Contractors Quality Systems-Assessment to the ISO 9000 Standard

by

Tawfiq Hasan Al-Atiq

A Thesis Presented to the

FACULTY OF THE COLLEGE OF GRADUATE STUDIES

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS

DHAHRAN, SAUDI ARABIA

In Partial Fulfillment of the
Requirements for the Degree of

MASTER OF SCIENCE

In

CONSTRUCTION ENGINEERING AND MANAGEMENT

December, 1996

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DHAHRAN 31261, SAUDI ARABIA

COLLEGE OF GRADUATE STUDIES

This thesis, written by **TOFIG HASAN AL-ATIG**, under the direction of his Thesis Committee and approved by all members, has been presented to and accepted by the Dean, College of Graduate Studies, in partial fulfillment of the requirements for the Degree of **MASTER OF SCIENCE IN CONSTRUCTION ENGINEERING AND MANAGEMENT**.

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This Thesis is dedicated to my parents, to my wife, to my son and daughter, and to my brothers and sisters

ACKNOWLEDGMENT

Acknowledgment is due to the King Fahd University of Petroleum and Minerals for support during my research.

I wish to express my appreciation to Dr. Abdul-Aziz Bubshait who served as my major advisor. I also wish to thank the other members of my Thesis Committee Dr. Sadi Assaf and Dr. Khaled Bubshait. Thank is also due to Abdul-Latif Al-Banian, Manager of the Committees Department in the Eastern Province Chamber of Commerce.

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التخصص : هندسة وأدارة التشييد

تاريخ الشهادة : ١٤١٧/٨هـ (١٢/ ١٩٩٦م)

ألتصقت صورة مشاريع التشييد بالجودة المتدنية والخطورة العالية والمنازعات التجارية بين المقاولين والزبائن . وقد ازدادت المطالبة على المقاولين بضرورة تفعيل أنظمة الجودة لديهم للتغلب على القصور الذي قد يحدث أثناء أعمال التشييد ولأعطاء الثقة للزبائن بأن مشاريعهم ستتم بطريقة صحيحة ومطابقة لمواصفاتهم . ومنذ أصدار الأيزو ٩٠٠٠ المواصفة العالمية لأنظمة الجودة ثار جدل كبير حول مدى ملائمته ببنوده ذات الصيغة العامة لمقاولات التشييد كون هذه المواصفة العالمية أكثر ملاءمة للصناعة منها لمقاولات التشييد .

وتمثل هذه الرسالة دراسة ميدانية للتعرف على أنظمة الجودة لخمسة عشر مقاولاً من مقاولي التشييد في المنطقة الشرقية من المملكة العربية السعودية ومدى تبنى هؤلاء المقاولين للأيزو ٩٠٠٠ ، وقد أوصت باختيار هؤلاء المقاولين الغرفة التجارية الصناعية بالمنطقة الشرقية وهم مصنفون من الدرجة الممتازة والأولى لديها .

وقد أظهرت الدراسة تبايناً في مدى شمولية أنظمة الجودة لدى المقاولين وأن أثنين من المقاولين قد حققا شهادة المطابقة للأيزو ٩٠٠٢ بينما هنالك أربعة مقاولين هم في الطريق لتحقيق ذلك وقد استقدم معظمهم مستشارين خارجيين من أجل هذا الغرض وأربعة اخرين ينوون تطبيق الأيزو ٩٠٠٢ في المستقبل . ويوجد بعض التحفظ لدى اثنين من المقاولين حول الأيزو بينما لا توجد فكرة لدى ثلاثة اخرون حوله

وقد أظهرت الدراسة أن بنود الأيزو حول الحفظ والتخزين ومراجعة العقود ومراحل الفحص والاختبارات هى الأكثر تطبيقاً لدى المقاولين بينما بنود تدقيق الجودة الداخلي وضبط التصاميم والأساليب الأحصائية والمسؤلية الأدارية وطرق التصحيح والوقاية هي البنود الأقل تطبيقاً لدى المقاولين .

درجة الماجستير في العلوم

جامعة الملك فهد للبترول والمعادن

الظهران ـ المملكة العربية السعودية

١٤١٧/٨هـ (١٩٩٦/١٢م)

THESIS ABSTRACT

FULL NAME OF STUDENT	**TAWFIQ HASAN ATIQ AL-ATIQ**
TITLE OF STUDY	**CONTRACTORS QUALITY SYSTEMS - ASSESSMENT TO THE ISO 9000 STANDARD**
MAJOR FIELD	**CONSTRUCTION ENGINEERING AND MANAGEMENT**
DATE OF DEGREE	**DECEMBER, 1996**

Poor quality and high risk have been associated with the image of construction industry for a long time. The existence of legal contracts is no guarantee that the client will ultimately be satisfied with his completed construction project. The demand is now increasing that construction contractors have to have in-house effective quality systems that can give the clients the confidence or assurance that they will get quality constructed projects on their lands.

This research provides a summary of an assessment of the quality systems of fifteen major construction contractors in the Eastern Province of Saudi Arabia, evaluated against ISO 9000 standard. The study revealed that the contractors quality systems vary in complexity ranging from informal inspection and test system to a comprehensive system where inspection and testing is only one element among many others. The study revealed that two contractors from the case studies have been already certified by third party to ISO 9002, and four others are in the process of being certified. Four contractors have long term plans to fully implement quality systems that meet ISO 9000 standard while three contractors are not familiar with the standard. The study disclosed that "Handling, Storage and Preservation", "Contract Review" and "Inspection and Test" are the clauses of ISO 9000 standard that the selected contractors most often comply with, while "Internal Auditing", "Design Control", "Statistical Techniques:, "Corrective and Preventive Action" and "Management Review" are the least. Documentation of the quality system lacking by the majority of the contractors.

MASTER OF SCIENCE DEGREE

KING FAHD UNIVERSITY OF PETROLEUM AND MINERALS

Dhahran, Saudi Arabia

CHAPTER 1

INTRODUCTION

1.1 Problem Statement

The evolution of Quality in all aspects of life has become more and more tangible. This interest in Quality is now very obvious in all types of businesses. Customers are now more demanding of quality. They do not only require their suppliers to provide quality products and/or services, but also require them to operate quality systems that provide them with confidence in getting consistent quality.

The emphasis on quality is also demanded in the construction industry. However, anyone who has a little knowledge of the construction industry would associate it with poor quality and high risk. This has been the construction industry's image for a long time. One of the possible solutions to overcome the

poor quality associated with the construction industry is to introduce and implement quality system standards (34).

One of these quality system standards is the ISO 9000 standard. ISO 9000 is an international standard intended to provide a generic core of quality system standard applicable to a broad range of industries and economic sectors. It sets out how a supplier - producing materials, equipment, services or facilities - can establish an effective quality system which will demonstrate commitment to quality and ability to meet customer's requirements. The reason behind establishing the ISO 9000 standard is to replace the different quality system standards set up by each industry, company and country with a common quality standard which is acceptable to all (45).

The ISO 9000 standard has been adopted by a large number of countries around the world, and applied in various industries including construction. Implementation of ISO 9000 standard as a model of quality management and quality assurance systems in the construction industry is not as wide as in other industries such as manufacturing and service industry (7).

This thesis is mainly a case study intended to survey selected construction contractors regarding their quality systems. Contractors' quality system elements are studied and compared with the requirements of ISO 9000 standard. The Eastern Province of Saudi Arabia is considered as the domain of the study.

1.2 Research Objectives

The objectives of this thesis are to :

1. Review ISO 9000 requirements and identify those requirements which apply to construction industry.

2. Provide interpretation of the ISO 9000 requirements for its applications in the construction industry.

3. Assess the extent of implementation of ISO 9000 standard's applicable requirements by the selected sample of contractors.

4. Finally, answer the following questions :

   - What are the quality assurance system elements required by the ISO 9000 standard that are most as well as least implemented by the selected contractors ?

   - How do the selected contractors perceive quality management and its application in the local construction industry ?

1.3 Scope and Limitations :

The research covers a sample of fifteen large construction companies in the Eastern Province of the Kingdom of Saudi Arabia. The contractors selected for the study were recommended by the Chamber of Commerce in the Eastern Province because they are classified as major contractors which have completed many construction projects. A longer list of contractors were contacted initially and their willingness to participate in the study was assessed. The selected fifteen contractors are among the first two classes of the Chamber's classification for construction contractors.

1.4 Thesis Overview :

This research consists of five chapters. The first chapter presents the problem statement, research objectives, scope and limitations.

The second chapter presents the literature review which is divided into two parts. The first part is a general history and background of ISO organization and the evolution of the ISO 9000 series of standards. Certification of quality systems and the relationship between ISO 9000 and Total Quality Management (TQM) is covered. The second part discusses the applications of ISO 9000 standard in the construction industry. First, the importance of quality systems in construction is presented. Then, interpretation of the ISO 9000 clauses to the

construction industry is discussed. The major requirements of the standard are highlighted and some example and discussion are given to clarify these requirements. Also, this part includes the difficulties faced in applying ISO 9000 standard by construction industry as compared to the manufacturing industry. In addition, This part provides a summary of the experiences of implementing ISO 9000 standard in several countries around the world.

The third chapter describes the methodology of the study explaining the steps followed in conducting the study, and data collection and analysis.

The fourth chapter of the research reports on the finding of the study following the interviews with the selected contractors. These findings are discussed in this chapter and the contractors quality systems implementation are assessed against the ISO 9000 standard.

Finally, the fifth chapter provides the summary of the study and presents, conclusions and recommendations for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview of ISO 9000 Standard

2.1.1 Introduction

ISO is the International Organization for Standardization, a worldwide federation of national standards bodies from 117 countries (16). ISO whose Central Secretariat is located in Geneva of Switzerland, is a non-governmental organization established in 1947 (20). ISO is not part of the United Nations Organization and its membership is not composed of government delegations, but is made of national standards institutes or organizations one member organization per country (12). The Saudi Arabian Standards Organization (SASO) represents Saudi Arabia in the ISO (16).

It is to be noted that "ISO" is not a name or an acronym. It was derived from the Greek word *isos which* means "equal", and is the root of the prefix "iso-" (e.g. "isometric" : equal dimensions). Hence, ISO was chosen as a name of the International Organization for Standardization as a reflection of its functions and because it is easy to follow (12).

2.1.2 Objectives of ISO

The objectives of the ISO is to develop world-wide standards to improve international communication and collaboration, and to promote the smooth and equitable growth of international trade. The output of ISO work is international technical agreements which are published as international standards (18). All of these international standards developed by ISO are voluntary, and ISO has no power to enforce their implementation in the member countries (12).

The scope of ISO covers standardization in all fields except electrical and electronic engineering, which are the responsibility of the International Electrotechnical Commission (IEC) (13).

ISO issued its first international standard titled "Standard Reference Temperature for Industrial Length Measurement" in 1951 (13). By the end of 1995, ISO had developed 10189 international standards according to the ISO statistics (15).

2.1.3 ISO Technical Committees

The technical work of ISO is carried out by technical committees (called TC's), one for each field. The ISO technical committees are assigned numbers in order of their establishment from TC 1 in 1947 to TC 212 in 1994, and so on (17).

Draft international standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an international standard requires approval by at least 75% of the member bodies forming a vote (22).

One of the well known ISO technical committees is TC 176, the one issued ISO 9000 international series of standards of quality management and quality assurance (17), which is the core subject of this thesis.

2.1.4 Evolution of ISO 9000 Standards

Since the Second World War, a trend has evolved which requires all materials, methods, machines and manpower to be coordinated and checked to ensure they work together to provide customer satisfaction. This need was first formalized in the form of US Military standard MIL-Q-9858A as the first quality

assurance standard issued in 1963. Although this old standard did not cover internal auditing, it contains most of the current elements of ISO 9000 standard (28).

The MIL-Q-9858A standard was followed by many quality assurance standards issued by different countries (see Table 1) until 1979 when the British standard BS 5750 was issued which became the basis for the birth of the international standard, ISO 9000, in 1987 (45).

TABLE 1 : Development of Quality Assurance System Standards (45)

Standard	Country	Year of Issue
MIL-Q-9858A	USA	1963
AQAP	NATO	1969
ANSI-N45-2	USA	1971
ASME Boiler Code	USA	1971
CSA-Z-299	Canada	1975
BS-5750	UK	1979
ISO 9000 Series	International	1987
ISO 9000 (Revision)	International	1994

2.1.5 Structure of ISO 9000 Family of Standard

Currently the ISO 9000 family of standards (previously called series of standards in the 1987 first edition) consists of 17 standards. These are listed in Table 2. As can be seen from Table 2, ISO 9000 is not a single standard, it's a

group (family) of standards. ISO 9001, ISO 9002 and ISO 9003 are used for contractual applications, i.e. supplier-customer business. Other standards in the ISO 9000 family are only guidelines, as their titles imply.

TABLE 2 : The ISO 9000 Family of Standards (14)

Standard	Title
ISO 8402 : 1994	Quality Management and quality assurance - Vocabulary
ISO 9000-1 : 1994	Quality management and quality assurance standards - Part 1 : Guidelines for selection and use
ISO 9000-2 : 1993	Quality management and quality assurance standards - Part 2 : Generic guidelines for the application of ISO 9001, ISO 9002 and ISO 9003
ISO 9000-3 : 1991	Quality management and quality assurance standards - Part 3 : Guidelines for the application of ISO 9001 to the development, supply and maintenance of software
ISO 9000-4 : 1993	Quality management and quality assurance standards - Part 4 : Guide to dependability program management
ISO 9001 : 1994	Quality systems - Model for quality assurance in design, development, production, installation and servicing
ISO 9002 : 1994	Quality systems - Model for quality assurance in production, installation and servicing
ISO 9003 : 1994	Quality systems - Model for quality assurance in final inspection and test
ISO 9004-1 : 1994	Quality management and quality systems elements - Part 1 : Guidelines
ISO 9004-2 : 1991	Quality management and quality systems elements - Part 2 : Guidelines for services
ISO 9004-3 : 1993	Quality management and quality systems elements - Part 3 : Guidelines for processed materials
ISO 9000-4 : 1993	Quality management and quality systems elements - Part 4 : Guidelines for quality improvement
ISO 10011-1 : 1990	Guideiines for auditing quality systems - Part 1 : Auditing
ISO 10011-2 : 1991	Guidelines for auditing quality systems - Part 2 : Qualification and criteria for quality system auditors
ISO 10011-3 : 1991	Guidelines for auditing quality systems - Part 3 : Management of audit programs
ISO 10012-1 : 1992	Quality assurance requirements for measuring equipment - Part 1 : Meteorological confirmation system for measuring equipment
ISO 10013 : 1995	Guidelines for developing quality manuals

An organization which intends to meet ISO 9001, 9002 or 9003 for contractual or certification purposes should first implement an internal quality management system based on the guidelines of ISO 9000-1 and ISO 9004-1. In other words, an organization must apply the standards on quality management before those on quality assurance (14).

2.1.6 System Versus Product Certification

The assurance of consistent quality is achieved by simultaneous application of two types of standardization :

- Product requirements (technical specifications)
- Quality system requirements.

These two types are complementary, and should not be confused. It is important to remember that quality system certification is different from product certification. System certification provides proof of capability, not product capability (14).

2.1.7 Certification to ISO 9000 Standard

As mentioned earlier, there are three standards among the ISO 9000 family of standards that are used for certification. These are ISO 9001, ISO 9002 and ISO 9003.

Before starting to explain the certification to ISO 9000 standards, one should understand the differences between 'first party assessment', 'second party assessment' and 'third party assessment' of quality systems. The differences between these assessments are as follows (45) :

- First party assessment (also called self-assessment) is performed by an organization to evaluate the adequacy of its own quality system and compliance with a standard such as ISO 9001.
- Second party assessment is performed by customers to examine the quality system of their suppliers.

However, second party assessment is expensive and time consuming for both parties (customers and suppliers), and this is why third party assessment and certification systems have been developed in order to reduce the need for multiple assessments and to provide impartial expertise as and when needed.

- Third party assessment is conducted by a body which is not party to any contractual relationships between clients and suppliers.

Certification bodies of quality systems provide confirmation that a supplier's quality system satisfies ISO 9000 applicable standard, or equivalent. The purpose of such certification is to give assurance that the supplier is capable of supplying products or services against appropriate standards (38).

The certification process involves a complete review and evaluation of the supplier's quality system. The process includes an initial visit (also called pre-assessment visit) made by the certification body to learn about the supplier's operations and to evaluate his readiness. Supplier's documentation is reviewed for compliance with the applicable requirements of the ISO 9000 standard. Deviations from the standard (called nonconformances) must be corrected by the supplier before the formal assessment is scheduled. The third party auditors verify by objective evidence that the supplier implements his own procedures, and that the procedures conform to the intent of the requirements of ISO 9000 standards. If the results of the assessment are satisfactory, the supplier will be granted the certificate (6). The certificate is usually valid for three years.

Companies whose quality systems are certified to ISO 9000 standard will be subjected to periodic follow up audits by the third party (called surveillance visits) to ensure that their quality system is continuing to function effectively (7). Surveillance visits are usually conducted every six months.

Oliver (33) in his article "further thoughts on ISO 9001" raised a reasonable concern on the certification process to ISO 9000 standards. He said that since ISO 9002 and ISO 9003 are extracts (subsets) from ISO 9001, why then do we need them at all. He added that one might argue that the existence of the three standards makes it possible to certify companies against appropriate standards rather than clauses within a standard. The response would be that this does not stop certification bodies awarding certification against ISO 9001 to companies, such as consulting engineers, architects and quantity surveyors, to whom many of the clauses of the standard do not apply.

In Europe, the number of certification bodies of quality systems increased rapidly in the 1980s. As a result, there was a risk of lowering the standards of the certification process (8). The situation necessitated the formation of national accreditation bodies, one in each country, to become responsible to control this increasing number of certification bodies and to improve and set up standards for certification methods. For example, In the UK, the National Accreditation Council of Certifying Bodies - NACCB (now called UK Accreditation Society after merging with the National Measurement Accreditation Service - NAMAS) was formed in 1985.

However, another problem was created. Suppliers' third party certification was only recognized in their countries since there are differences in standards between each European national accreditation body and the other. European suppliers struggled to have multiple certifications to sell their products in other

countries (46). For example, a German supplier needed to achieve a certificate from British Standards Institute - Quality assurance (BSI QA) or Lloyd Register - Quality assurance (LR QA) to seil his products in the UK, and have another certificate from Det norske Veritus (DnV) to sell his products in Norway, and so on; this was in addition to maintaining his certificate from the Technicher Uberwachungs Verein (TUV) in Germany, for example, to sell his product in his home country.

This was a problem which was realized by Europe and was the reason to form a new organization, the European Accreditation of Certification (EAC) made up from the national accreditation bodies. In 1989, a European standard EN 45012 was issued to be common bases for the requirements of certification bodies in Europe at large, with the objective that any ISO 9000 certificate issued in any European country would be recognized in all other European countries (46).

The European countries whose certification bodies are accredited to EN 45000 standards are Austria, Belgium, Switzerland, Czech Republic, Germany, Denmark, Spain, Finland, UK, Ireland, Italy, Norway, The Netherlands and Slovak Republic (8).

Schaaf (44) criticized the process of certification to ISO 9000 by raising the following concerns :

- The standard requires too much documentation .
- The certification process is very expensive for suppliers to implement.

In Saudi Arabia, the number of certified companies has increased from 4 in the beginning of 1993 to 98 in the end of 1995 (see Table 3).

TABLE 3 : ISO 9000 Certification Growth in Saudi Arabia (42)

Date	Number of Certified Companies
January 1993	4
September 1993	10
June 1994	30
March 1995	53
December 1995	98

Independent quality system certification services are available to the local companies by :

- Saudi Arabian Standardization Organization (SASO)
- International bodies who have offices in Saudi Arabia, i.e. the Society Generale de Surveillance (SGS), the American Bureau of Shipping (ABS-QA) and the Technicher Uberwachungs Verein (TUV).

- International certification bodies who have offices out of the Kingdom such as the British Standard Institute (BSI), Lloyd Register, Germanischer Lloyd, Det norske Veritus (DnV) and Bureau Veritus, etc.

Other national companies are also planning to enter the quality systems certification arena.

2.1.8 ISO 9000 and TQM

Total Quality Management (TQM) is a company-wide effort that involves every person in an organization to improve performance. It penetrates to every aspect in the organization and puts quality as a fundamental objective.

TQM philosophy which is based on management commitment, as the name implies, focuses on (4) :

- Continuous process improvement and innovation
- Customers and suppliers (both internal and external) involvement
- Team work
- Education and training

in an effort to achieve (4) :

- Customer satisfaction
- Cost effectiveness, and
- Defect-free work

TQM has been applied not only in manufacturing but also in the construction industry. Japanese construction companies began implementing TQM concepts in their companies in the 1970s. Since then, three construction companies have been awarded the Deming Award, the TQM Prize for TQM in Japan with the name of Dr. Edward Deming, the American person who propagated the TQM philosophy in Japan (4).

The relation between the philosophy of TQM and ISO 9000 is debatable.

ISO 9000 is a route to TQM, they are complementary to one another. For companies who are implementing TQM, installing ISO 9000 will be relatively straight forward. On the other hand, if a company is planning to implement TQM, it can use ISO 9000 as a vehicle (10).

There is no contradiction between TQM and having a quality assurance system that is built to ISO 9000 standard. In fact, the two systems can be integrated to achieve the TQM/QA common goals. In addition, quality assurance provides measurement which any TQM needs for monitoring continuos improvement (23).

2.2 ISO 9000 and the Construction Industry

Procurement of construction projects is not simple. The existence of legal contracts is no guarantee that the client will ultimately be satisfied with the completed project. Even if after a problem occurs and the owner (client) of a project eventually obtains compensation by arbitration, the client cannot obtain replacement. He is left with the patched-up original which will probably be a continuing source of irritation and unanticipated expense (35).

Therefore, the client requires the contractor to have an in-house effective quality system that can give him the confidence or assurance that he will get a quality constructed facility on his land. This is what is called a "quality assurance system".

Quality systems involve internal and external aspects. Internal quality systems cover activities aimed to provide confidence to the management of an organization that the intended quality is being achieved. This is called a "quality management system". By successful implementation of quality management systems, companies should be able to demonstrate to their management that introduction of such a system has materially benefited the company not only increasing the quality of products and workmanship but also through increased efficiency, decreased in waste and increased in profitability.

Also, through regular audits and evaluation, problems in implementing the quality system can be identified and corrected, thereby enabling staff to function

within a well defined environment with clear lines of responsibility. With the back up by internal audits, the system can identify areas of efficient working operation, and those which require more effort for improvement (33).

Quality management goes further than just requiring systematic and documented procedures for doing construction work, and emphasizing on reaction to problems. It is important not only to identify problems and eliminate their causes, but also to prevent them from happening in the first place. Wasteful and costly re-work activities are often accepted as routine and considered unavoidable. The organization which trains its staff to identify potential problem areas and treat them effectively will realize, by their elimination, the benefit of quality management (25).

On the other hand, external quality system covers activities aimed to provide confidence to the client that the supplier's quality system will provide a product or service that will satisfy his quality requirements. This is called "quality assurance systems" (39). Contractor's quality assurance system is very important to the clients, who will gain confidence that 'getting it right first time' will be the contractor's norm (11).

2.2.1 Responsibility for Quality

Quality and excellence in construction is achieved through a team effort of the owner, engineer, contractor, material supplier, inspection agency, testing firm and technical consultant as they are involved in the project (2). The following are some responsibilities of the three main parties of construction projects; namely the client, the designer and the contractor :

2.2.1.1 The client :

The client or his representative is responsible to :

- Prepare the project brief which defines the project quality requirements. He should be realistic in considering the relationships between cost and performance, appearance and function (36)
- Prequalify and procure the design, construction and commissioning of the intended project, by careful selection of capable firms (35)
- Finance the project and provide prompt payment to the other parties as required by the contract (36).

2.2.1.2 The Designer :

The Designer is responsible to (35) :

- Prepare the required design to ensure that the functional and aesthetic characteristics of the design satisfy the requirements of the client's brief
- Interact with the client to amend his requirements as a result of cost estimates, and provide options
- Provide information that enables the contractor to work to the specifications and maintain the construction program
- Monitor the quality of the construction, if requested by the client.

2.2.1.3 The Contractor :

The Contractor of the project (also called the constructor) is responsible to (35) :

- Construct the work in accordance with the drawings and specifications of the project
- Ensure that the project site operations conform with his quality procedures
- Ensure that the quality of procured materials, products, equipment and services, and installation comply with the specified quality requirements.

In the case of design-build contracts, the role of the contractor will include the role of the designer mentioned in 2.2.1.2 above.

2.2.2 Quality Systems in Construction Industry

Burati (5) conducted a study on nine fast-track construction projects to analyze the effects of the various deviations on the overall projects. The study revealed that the deviations in the projects accounted for 12.4% of the total projects cost. Design deviations were found to be 9.5% of the total project cost while construction deviations were 2.5%. The study also revealed that design deviations average of 78% of the total number of deviations (79% of the total deviation cost). On the other hand, the construction deviations accounted for 16% of the total number of deviations (17% of the total deviation cost).

It can be concluded from this study that the industry is loosing a lot of resources that can be saved if there is better checking and control over the design and construction phases of the project. This support the need for an effective quality assurance system.

There has been a realization that quality assurance has little added value to the construction industry unless it impacts positively on the quality of product - finished facility -for the benefit of the industry clients (41).

Benefits of contractor's quality management system include continuing awareness and improvement of quality by its personnel, reputation, competitiveness in the market, reduction in scrap, rework, repair, returns, claims and warranty costs.

This will increase the customer's confidence in the contractor that the facility to be constructed meets specified requirements and is fit for the intended use (36).

2.2.3 Applications of ISO 9000 standard

ISO 9000 standards were not written for any specific industry. The standard is generic and is intended to apply to all industries. Therefore the standard is applicable to manufacturing, service, processing, construction, and other types of industries (26). The standard's requirements may be interpreted differently by each industry which is the intention of the ISO/TC 176 Committee (ISO technical committee responsible to write international standards on quality management and quality assurance subjects (17)). This can be clearly seen in the Introduction section of the ISO 9001, 9002 and 9003 standards, where it is stated that "..they are generic and independent of any specific industry or economic sector." (21).

2.2.4 Problems in Implementing ISO 9000 Standard in the Construction Industry

The British Construction Industry Research Institute (CIRIA), which published interpretation of the ISO 9000 standard for the construction industry, believes that ISO 9000 standard was written with manufacturing in mind (40). This CIRIA's Special Publication 74 states that the standard has the following two significant disadvantages to the construction industry (40) :

1. Its terminology is biased towards manufacturing, and is difficult to understand in the construction arena.
2. It is structured in a way which does not reflect the way in which the construction industry works.

There are special features in construction projects and practices that are different from manufacturing, that make the use of ISO 9000 standard in manufacturing wider than in construction. The following are some of these features :

- Almost every construction project, either partially or totally, is a prototype by itself with different requirements and specifications (39).
- Almost every construction project is a unique collection of people, equipment and materials brought together at a unique location under unique weather

conditions, while most manufacturing is mass production where all of these factors are consistent producing typical products over and over again (26).

- Performance testing is generally not feasible as a basis of acceptance (39).
- It is common to have separate contracts for design and construction (39).
- It is not feasible to reject the whole constructed project after completion while attached to the purchaser's land (39).
- Decisions to reject a defective part of a constructed project need to be taken promptly before succeeding parts are constructed or installed (39).
- The number of parties involved in the constructed projects procurement: (i.e. client, designer, project manager, contractor, sub-contractors, materials or equipment suppliers, and inspection or testing agencies) are more than those involved in manufacturing procurement. Achieving quality construction requires effort from all of these parties. This makes the interface and responsibilities of the various individuals and organizations more complicated than in manufacturing (34).
- The organization structure of a construction company will vary depending on the nature of the project, while organization structure in a manufacturing company is almost un-changing. This will affect the smoothness of communication and interface between the responsible individuals (26).

- Turn-over of manpower in construction is higher than in manufacturing, which affects the effectiveness of long term plans.

- Construction projects are very complicated and their execution may takes years

Some of these features might also be applicable in manufacturing in rare cases.

The European Construction Industry Federation (FIEC) survey report of 1993 showed that lack of guidance, bad consulting work, heavy administration procedures on site and too much paperwork were considered as the main reasons behind slowing the adoption of ISO 9000 by the construction industry (7). Table 4 lists the clauses of ISO 9001 standard which represents difficulty in their applications or have little use in construction as reported by the FIEC survey in 1995 (8).

TABLE 4 : Clauses of ISO 9001 Standard That Are Difficult to Apply or Have Little Use in Construction (8)

ISO 9001 Clause	Title of the Clause	Concerns
4.2	Quality system	Statistical methods are not applicable
4.5	Document and data control	Difficult to apply
4.6.2	Evaluation of Sub-Contractors	Difficult to apply
4.7	Control of customer-supplied product	Little use
4.8	Product identification and traceability	Little use
4.12	Inspection and test status	Difficult to apply
4.13	Control of nonconforming product	Difficult to apply
4.14	Corrective and preventive action	Difficult to apply
4.15	Handling, storage, packaging, preservation and delivery	Little use
4.19	Servicing	Little use
4.20	Statistical techniques	Little use

A study by Pheng (46) identified the following as the main difficulties facing implementation of ISO 9000 standard in construction:

1. Lack of control over or cooperation from the subcontractors nominated by the owner
2. High foreign labor control and shortage of skilled workers
3. Lack of training in quality concepts
4. Confusing technical terms
5. Difficulty in coping with new roles and responsibilities
6. Insufficient checking of works by the contractors' site staff before the inspection by the owner's inspectors
7. Poor response in filling out standard forms
8. lack of participation from consultants in quality management
9. High turnover rate of staff.

2.2.5 Criticism to ISO 9000 Applications in the Construction Industry

Although it has received wide acceptance around the world and is adopted by more than 70 countries, there are opponents to the ISO 9000 standard (7). In the UK, for instance, the following are some examples of the criticisms reported from anti's of BS 5750 (British national standard equivalent to ISO 9000 standard) and its adoption in the construction industry :

- The construction industry does not need BS 5750 and that it does not work anyway. The standard cannot be compared to the Japanese example, where QA managers or departments are unknown and quality control comes direct from established work practices and compliance (29).
- The BS 5750 is an unacceptable paperwork system (29).
- The BS 5750 is relevant but still some work is to be done on how to apply it in construction work (29).
- The standard is a vague and badly written document. It does not seem to have been written with building or civil engineering in mind (25).
- Contractors are different from manufacturers whose routine processes can be monitored closely everyday. They - contractors - are not confined to a fixed work location and environment; hence should not be offered blanket ISO 9000 certification, but rather be awarded only on a project-to-project basis (22).

The BSI QA Certification officer defended the BS 5750 and said that the standard is relevant to the construction industry and that the standard requires careful interpretation. Criticism is being driven by those who do not understand either the standard or the industry, he added (30).

2.2.6 ISO 9000 Standard and the Construction Industry

As mentioned earlier, the three standards of ISO 9000 family that are used in external businesses are ISO 9001, ISO 9002 and ISO 9003. ISO 9001 is the most comprehensive one while ISO 9002 is a subset of ISO 9001, and ISO 9003 is a subset of ISO 9002.

The differences between the quality system elements required by the ISO 9001, ISO 9002 and ISO 9003 is summarized in Table 5. In a quality system based on ISO 9001 standard, three elements of the system are considered the most important ones; these are (45) :

- Design Control
- Purchasing
- Process Control

CIRIA Special Publication 84 mentions that the existing ISO 9000 standards consist basically of model specifications for quality systems, drawn up for manufacturing industries without regard to the special characteristics of the construction industry. Because of this, quality system requirements as part of contracts might be subjected to dispute between the parties (39). Therefore, interpretation of the requirements of each of ISO 9001 standard elements is very important.

TABLE 5 : The Differences Between ISO 9001, ISO 9002 and ISO 9003 (21).

Clause No.	Title of the clause	ISO 9001	ISO 9002	ISO 9003
4.1	Management Responsibility	F	F	L
4.2	Quality System	F	F	L
4.3	Contract Review	F	F	N
4.4	Design Control	F	N	N
4.5	Document and Data Control	F	F	L
4.6	Purchasing	F	F	N
4.7	Purchaser Supplied Product	F	F	N
4.8	Product Identification and Traceability	F	F	N
4.9	Process Control	F	F	N
4.10	Inspection and Testing	F	F	L
4.11	Inspection Measuring and Test Equipment	F	F	L
4.12	Inspection and Test Status	F	F	L
4.13	Control of Nonconforming Product	F	F	L
4.14	Corrective and Preventive Action	F	F	N
4.15	Handling, Storage, Packaging and Delivery	F	F	L
4.16	Quality Records	F	F	L
4.17	Internal Audits	F	F	N
4.18	Training	F	F	L
4.19	Servicing	F	F	N
4.20	Statistical Techniques	F	F	L

F : full requirement; L : less stringent requirement; N : not required.

2.2.7 Interpretation of ISO 9000 standard in the construction industry

As mentioned earlier, ISO 9001 is the most comprehensive standard among the ISO 9000 family of standards. Hence, in this section an interpretation of ISO 9001 clauses to the construction industry is presented.

The standard consists of four main sections following the "Introduction" section, as follows :

1. Scope and field of application
2. References
3. Definitions
4. Quality system requirements

Section 4 addresses the twenty clauses of the quality system requirements. Therefore, the quality system requirements are numbered from clause 4.1 "management responsibility" up to clause 4.20 "statistical techniques". Interpretation of these twenty clauses is given below. Each clause of the standard is discussed. First, the major requirements are listed. Then, details of specific requirements will be explained. Table 6 lists the clauses of the standard and the specific requirements under the clauses that are discussed.

TABLE 6 : Clauses of the ISO 9001 Standard and the Sub-topics Under Each Clause

Title of the clause	Sub-Topics
Clause 4.1 Management responsibility	• Quality policy • Responsibility and authority • Resources • Management Representative • Management review
Clause 4.2 Quality System	• Quality manual • Quality system procedures • Quality plans
Clause 4.3 Contract Review	
Clause 4.4 Design Control	• Design plans • Design input and output • Design review and verification • Design validation
Clause 4.5 Document and Data Control	
Clause 4.6 Purchasing	• Evaluation of sub-contractors • Purchasing data • Surveillance of sub-contractors
Clause 4.7 Purchaser Supplied Product	
Clause 4.8 Product Identification and Traceability	
Clause 4.9 Process Control	• Equipment maintenance • Special processes
Clause 4.10 Inspection and Testing	• Inspection and test procedures • Receiving inspection and testing • In-process inspection and testing • Final inspection and testing • Inspection and testing records
Clause 4.11 Inspection Measuring and Test Equipment	
Clause 4.12 Inspection and Test Status	
Clause 4.13 Control of Nonconforming Product	
Clause 4.14 Corrective and Preventive Action	
Clause 4.15 Handling, Storage, Packaging and Delivery	• Handling • Storage and preservation • Packaging and delivery
Clause 4.16 Quality Records	
Clause 4.17 Internal Audits	
Clause 4.18 Training	
Clause 4.19 Servicing	
Clause 4.20 Statistical Techniques	

Clause 4.1 : Management Responsibility

Under this clause, the standard requires the contractor's management to (22) :

- Establish and document a quality policy that expresses intention and commitment to quality
- Define and document the responsibility, authority and interrelation of all personnel, especially the QA/QC personnel
- Provide adequate resources including trained and qualified manpower required to achieve quality objectives
- Delegate an individual from the executive management (called the "management representative" by the standard) and assign him the responsibility to run and support the quality system
- Conduct and document regular reviews - by top management - of the quality system to evaluate its effectiveness in meeting the intended objectives.

The standard realizes the importance of management commitment to the success or failure of any quality system. This is why it has been put as the first requirement in the standard for quality systems.

Quality Policy

The responsibility for and commitment to a quality policy belongs to the highest level of management, and that the quality policy should be consistent with the other company policies. In this quality policy, management should define its objectives regarding quality, such as fitness for use, performance, safety and reliability (39).

Responsibility and Authority

Adequate quality in construction can be best achieved through cooperative activities by all personnel, including those who are responsible to manage and direct the quality program and establish policies and objectives (management), and those individuals who implement the construction work (staff) and verify conformance to quality requirements (QA/QC personnel). In other words, the responsibility of quality cannot by limited to one group. Since every individual has a role to play, the various responsibilities and authorities must be defined, documented and understood by the respective functional groups and individuals (37). It is necessary to allocate responsibility and authority to individuals and to allow them sufficient freedom to pursue any matter to a satisfactory conclusion (39).

The wrong conception about quality systems is that it is the responsibility of only an individual or group that will be instructed to simply look at the

regulations. and -in isolation- sort out ways to prepare procedures and manuals just to satisfy the external auditors. In this case, there is little interaction and communication between the quality assurance and its peer departments such as purchasing, construction, engineering, and project management. The quality assurance department ends up not being involved in the day-to-day project activities, and the result is sacrificing quality (23).

Personnel involved in verification of quality should be free from the pressure of cost and schedule, and should be given the authority and independence to perform their role effectively (36). Authority and freedom must be given to contractor's QA/QC personnel who are responsible to take necessary actions to assure compliance at site with the project contract documents (43). The contractor's organization chart must be developed to indicate the relation between the functional groups and reporting lines (40).

Resources

The standard requires the contractor to identify the resources required for management, performance of the work and verification, including trained human resources, equipment for design, construction, inspection and measuring; and to make these resources available (26).

In the 1987 revision of the standard, this sub-clause (4.1.2.2) focused on the verification resources only. However, the 1994 revision included not only the

verification but also other resources, namely management and production personnel.

Management Representative

To strengthen the quality system, the standard requires the supplier to appoint an individuai within executive management to be responsible to ensure that the system is implemented, maintained and effective (39).

In some companies, the management representative is called the quality manager or quality system manager (39).

The Management representative might be full-time or part-time depending on the size of the construction company. Also there might be two levels of management representatives : one is responsible for the corporate quality system and another responsible for project quality systems; again depending on the size of the project. In the former case, the management representative will report to the organization chief executive, while in the latter, the management representative will report to the project manager (40).

Management Review

The standard requires the quality system to be regularly reviewed by the executive management including the senior management board and the designated management representative to evaluate its suitability and effectiveness in achieving the quality policy. This review should include such

matters as the efficiency of the current quality system and the need to change it, and to review quality problems brought to life during internal audits, external quality audits, or as the results of customer complaints. Minutes of these reviews shall be documented (40).

Clause 4.2 : Quality System

Under this clause, the standard requires the contractor to (22) :

- Implement a documented quality system to ensure that construction projects conform with the project requirements
- Prepare a quality manual that covers the requirements of the ISO 9001 standard
- Prepare quality procedures that are required by the ISO 9001 standard and the quality policy
- Define and document how the requirements for quality will be met

The Contractor 's quality system is required to assure the achievement of an acceptable project in accordance with the contract documents (43). This clause clearly indicates that the fundamental purpose of the quality system is to ensure that the product conforms to specified requirements (39). The quality system should function in such a manner as to emphasize problem prevention rather than dependence on detection after occurrence (i.e. pro-active

versus re-active types of systems). This clause has been identified by the FIEC European survey report as one of the clauses that present difficulties in their application in construction (8).

Quality Manual

A Quality manual is considered the first level of the quality system documentation. It should address all applicable requirements of the ISO 9001 standard and overview and reference the quality system procedures. The ISO 10013 standard provides guidelines on how to write quality manuals.

Quality System Procedures

Quality procedures are the second level of the quality system documentation. The ISO 9001 standard requires 23 quality system procedures, as a minimum. These are given in Table 7.

Each quality system procedure should be clearly written so that it will define

(28):

- Purpose and scope
- Definition of responsibilities
- Step-to-step Method of performance of the required activity
- Materials and equipment required
- Documentation to be used.

TABLE 7 : Quality System Procedures Required by ISO 9001 (22)

	Required Procedures	ISO 9001 Clause
1	Contract review	4.3.1
2	Design control	4.4.1
3	Document and data control	4.5.1
4	Purchasing	4.6.1
5	Control of customer supplied product	4.7
6	Product identification and traceability	4.8
7	Process control and manner of production	4.9 a
8	Inspection and testing	4.10.1
9	Receiving Inspection and testing	4.10.2
10	In-process inspection and testing	4.10.3
11	Final inspection and testing	4.10.4
12	Control, calibration and maintenance of measuring and test equipment	4.11.1
13	Control of nonconforming product	4.13.1
14	Handling	4.15.1
15	Storage	4.15.1
16	Packaging	4.15.1
17	Preservation	4.15.1
18	Delivery	4.15.1
19	Control of quality records	4.16
20	Internal quality records	4.17
21	Training	4.18
22	Servicing	4.19
23	Statistical techniques	4.20.1

Procedures must be simple and straight forward so that they can be understood and easily executed (36). They should be written to be followed not to impress (39).

Procedures should indicate acceptance criteria to be satisfied. They should be written in such a manner that would make it possible to measure extent of compliance objectively (39).

Quality Plans

The quality plan is the third level of quality system documentation. It plays a very important role in controliing construction quality. A quality plan spells out the various processes and sub-processes associated with a job, and sets out the responsibilities for each member of the construction team. It also specifies the applicable work and applicable documents as well as acceptance criteria (11).

It was recognized that in structuring the quality system, it is necessary to build an element which considered variations in clients requirements, one for every project. It specifies the quality requirements to be followed, the organization structure, responsibilities of the various personnel and parties (26).

Clause 4.3 : Contract Review

Under this clause, the standard requires the contractor to (22) :

- Conduct thorough reviews of bid requests prior to submission of tenders and review contracts prior to acceptance, to ensure that the bids and documents are clear, complete an achievable
- Document procedures for the contract review, implement them and maintain the records of the reviews
- Communicate contract requirements and amendments to the contractor's concerned functional groups

This clause of the standard can simply be expressed as "understanding customer's needs" (45). The contractor's review is necessary to resolve the problems associated with the clients drawings and specifications which frequently might be incomplete, inaccurate and ambiguous (40).

The standard requires the contractor to review the customers' contract documents for "biddability" and "constructability", and to discover interface problems and resolve conflicts between the contract documents and existing site conditions (27).

By this review, the contractors should fully understand the requirements stated in the contract documents including the technical specifications. A prompt request to the client for clarification of ambiguities in the contract documents and resolution of discrepancies will lead to a more possibly successful project and avoid disastrous results such as disputes, arbitration and litigation and thus result in saving resources, which is the goal for all parties involved in the construction business. The contractor should understand the design of each element which can be critical to the integrity of the system to be constructed. If the contract language provides unclear intent by using terms such as "to the satisfaction of the engineer" or "to a reasonable...", this should be resolved with the specifier (24).

Bayless (2) suggested that in fairness to all bidders, the owner should specify in detail the level of quality control he expects on his project . Contractors should inquire about the client's requirements on level of quality

control, and provide firm allowance to each bidder for inclusion in his bid. This is to overcome the problems created in the competitive-bidding arena where the contractors face difficulty in estimating the cost of QC which results in "cutting-corners" at the execution stage of the project.

This clause has been identified by the FIEC European survey report as one the clauses that presents difficulties in their application in construction (8). The argument is also supported by CIRIA Special Publication 84 which indicated that the clause is difficult to apply especially in competitive tendering situations (39).

Clause 4.4 : Design Control

Under this clause, the standard requires the contractor to (22) :

- Establish, document and implement procedures to control and verify the design for construction projects
- Prepare and update plans for design activities
- Identify, document and review the design input required for the various construction works
- Document and review the design output
- Conduct and document independent design review at selected stages

- Perform and record design verification at selected stages
- Perform design validation
- Identify, document, review and approve design changes and modifications

This clause is only applicable for contractors who perform design in addition to construction and installation. It does not apply to the contractor if the design is performed by separate organizations (39). Design control is essential in detecting errors in design calculations, omissions, ambiguity and inadequacy of drawings and specifications (27).

Establishing a formal design review program is very important. It is to be conducted by qualified professionals to identify deficiencies and incorporate improvements into the design documents. This is considered an integral part of the quality assurance system.

A study conducted by Kirby (27) showed that 56% of the causes for contract modification are due to design deficiencies; other major causes are owner requested changes and unknown site conditions.

Greater participation by the design engineer in the construction project as it progresses is very important. Plan details which are not clear or complete should be discussed and resolved. Long-term benefits can be achieved if the engineer is provided feedback about his design, such as the ease or complexity of its implementation. A common problem in construction is that of resolving

problems associated with the design plans by the contractor and QC personnel, while this can be better handled by the design professional (2).

Design Plans

Design plans are required to coordinate and organize the design activities and focus on critical areas. They usually include (39) :

- Identification of responsibilities for each design activity
- Description of the design activities
- Description of design verification activities

The design plan becomes more in demand if the design is a "non-standard" type (39), and when there is more than one design team involved (40).

Design Input and Output

Clear information required for the design input must be available so that the necessary design work can get fully underway (45). Design input is very important because it is the basis for the design work (40). Unlike the conventional way where the client states his requirements, the contractor must take the initiative in specifying the required information (inputs) that he requires for the design (39). The design input must be reviewed to ensure that all required information to carry out the design is clear, and to ensure that any conflicting or

ambiguous requirements are resolved or clarified. Examples of design inputs in civil engineering design include (32) :

- Codes and standards
- Basic functions of structures and buildings
- Design load
- Site data
- Environmental conditions
- General layout drawings, etc.

On the other hand, design output includes (32) :

- Calculations
- Drawings
- Specifications, etc.

These shall be prepared according to the procedures or standard-type documents (32).

The standard requires design output to include or reference acceptance criteria, and to identify critical areas that require special care during construction or service (39).

Design Review and Verification

The standard requires independent review of design output by personnel other than the one who performed the design. Design review is one of the

acceptable methods required for verifying the adequacy of design work. Other alternative verification methods are (39) :

- Performing alternative calculations
- Comparison with a similar proven design
- Undertaking tests and demonstration

Design Validation

Computer programs used for design can only be used if they are qualified or validated to ensure that they will generate correct results. This can be done by (32) :

- Verification by alternative design
- Significant test calculations
- Independent verification of the algorithms

Clause 4.5 : Document and Data Control

Under this clause, the standard requires the contractor to (22) :

- Establish, implement and maintain documented procedures to control internal and external documents and data

- Review and approve the documents and data for adequacy
- Establish and update a master list that identifies the current revision status of the documents
- Make available updated copies of the documents at the locations where they are required and remove the obsolete ones
- Review and approve changes to the documents by authorized personnel who performed the original review and approval

The control required in this clause covers all documents that are related to quality which are issued and liable for revision (40). This is important to ensure that the availability of current information -included in the documents - is communicated to those who have need for it (36), and to avoid people working to superseded documents or without relevant documents (39).

Controlled copies of the quality documents should be located at the construction site and made accessible to the people who implement them (37). Establishing distribution lists for each document is helpful to ensure its availability with concerned personnel (32).

The quality documents to be controlled are internal and external documents. The internal quality documents include (39) :

- Contract conditions
- Drawings
- Specifications
- Quality manual
- Quality procedures
- Quality plans
- Inspection and test plans
- Work instructions
- Operation sheets

These documents should be prepared using standard format and should be uniquely identified, indicating the approval authority, revision number and date of issue. They should be written in simple language so that their implementation will be straight forward (37). In revising and updating procedures, one should understand that results govern procedures; the opposite is not true (9). On the other hand, external quality documents include industry standards, and client's drawings and specifications (39).

Clause 4.6 : Purchasing

Under this clause, the standard requires the contractor to (22) :

- Establish, implement and maintain documented procedures for purchasing to ensure that the purchased product or service conforms to specified requirements
- Pre-qualify, select and evaluate sub-contractors who are capable of meeting sub-contract requirements
- Define and exercise the necessary extent of control over sub-contractors
- Maintain performance data and quality records for acceptable sub-contractors
- Include and specify all technical and quality requirements in the sub-contract documents reflecting the client's requirements stated in the main contract
- Review the sub-contract (procurement) documents and approve them before issue
- Specify in the sub-contract documents the arrangements of verification by the contractor and/or the client, per the contract requirements, at the sub-contractor's facilities.
- Perform quality surveillance activities at sub-contractor's facility, to the extent required, to verify that the procured product or service complies with the requirements specified in the procurement documents

The contractor shall ensure that the materials or services procured for its projects are purchased from qualified sub-contractors. The procured materials

or services, and the sub-contracted work shall comply with the customer contractual requirements (36).

Studies (3) have shown that lack of procurement systems for construction materials is a recognized problem associated with the construction industry causing a decrease in productivity and wasting of money. Poor quality materials cause major construction rework and late shipment cause project milestones and contract deadlines to be missed. The selection of proper and qualified vendors has a major impact on the overall performance of the whole construction project. Statistics show that material represents a large portion (50-60%) of construction costs. The construction industry spends only 0.15% of its cost on material management while manufacturing spends 1.0%. The Construction Industry Institute reported that better material management can increase between 6-12% of craft labor productivity, which is a cost saving for both contractor and client.

This clause has been identified by the FIEC European survey report as one of the clauses of the ISO 9000 standard that present difficulties in their application in construction (8).

Evaluation of Subcontractors

The term "sub-contractor " here does not only refer to organizations or individuals who supply partial construction work, but also includes the suppliers of products (e.g. suppliers of construction materials or equipment) and services (e.g. inspection agencies or testing laboratories) (39).

Sub-contractors play important roles in construction projects, and their selection is a critical initial step. Their performance has a significant effect on the success or failure of any construction project (3).

The contractor should have a formal system for supplier selection based on objective assessment of the capability of each sub-contractor. There must be a clear set of evaluation criteria for the selection system to be objective, consistent and uniform (3). The contractor should select only sub-contractors who have the capability to meet sub-contract and quality assurance requirements (32).

Performance of sub-contractors is to be measured by the contractor by collecting historical data on critical criteria such as (3) :

- Product quality based on receiving inspection at site
- Meeting delivery schedules specified by the sub-contract documents
- Meeting delivery time schedule and quality of documents such as material submittals, test certificates, operating and maintenance manuals, etc.
- Timely responsiveness to rejected submittals
- Responsiveness to problems such as bringing technical personnel promptly to fix any problems that arise during procurement or after delivery of products
- Number of warranty calls and customer (project owner) satisfaction

The contractor is required to keep records of approved sub-contractors including past assessment (45). These records must be subject to periodic update, incorporating performance and inspection information. This will enable contractors to use qualified suppliers and contractors on the site (11), and also as an aid for future sub-contract selection (39).

Purchasing Data

The sub-contract (procurement) documents should be complete and include all necessary requirements, such as (37) :

- Clear identification and description of the subcontracted work to be performed including specifications, drawings, required inspection and testing, and industry standards with revision issues.
- Performance schedule and location
- Requirements for approval or qualification of procedures, processes, equipment and personnel.
- Requirement for documentation or test certificates.

In case of material procurement, the contractor's purchasing documents should also include requirements for identification of the items, marking and packaging (22).

In both cases, the procurement documents should state the requirement of the contractor and the project owner to have the right to perform source

inspection to verify that the supplied material or sub-contracted work complies with the procurement documents (36).

Surveillance of Sub-Contractors

Controlling the quality of sub-contracted work or purchased items is essential to the total effectiveness of the contractor's quality system. Therefore, the contractor is responsible to exercise all necessary measures including performing surveillance activities at the sub-contractor's facility. This is also called source inspection. Source inspection becomes a necessity if the characteristics of the procured item cannot be verified during subsequent processing such as receiving inspection or review of test reports. The contractor is ultimately responsible for verification of the quality of sub-contracted works or procured items which cannot be substituted by the verification (inspection) of the client (37).

Clause 4.7 : Control of Customer-Supplied Product

Under this clause, the standard requires the contractor to (22) :

- Establish, document, implement and maintain procedures for dealing with the product supplied by the customer for incorporation into the construction project

- Verify, store and maintain the customer's supplied product
- Record and notify the customer of any detected unsuitability of these products

The product mentioned in this clause does not only include the special materials supplied by the customer (free issue supplies), but also the drawings and survey data related to the project site supplied by the client to the contractor (40). CIRIA Special Publication 84 questions whether this clause applies to the design, data, information and even the site supplied by the customer to the contractor. The Special Publication 84 suggests that this clause "should be amended to clarify its intended requirement" (39). FIEC's European survey report showed that this clause has little use in construction (8).

Clause 4.8 : Product Identification and Traceability

Under this clause, the standard requires the contractor to (22):

- Establish, implement and maintain documented procedures to identify - by a unique identification using tags or marking - each lot, component or part to the applicable drawing, specification by relevant drawings, or other documents, throughout all stages of construction
- Establish, implement and maintain documented procedures for maintaining traceability of every aspect of the construction work back to materials or batch supplied, if traceability is a specified requirement.

- Maintain traceability records.

This clause applies for purchased material and equipment. The main objective of identification is to ensure that each item is used for the activity for which it was intended. The identification will appear on all relevant construction documents and inspection records (37). This clause does not apply to the ultimate construction product (e.g. foundation or column) since it has a fixed location and does not require separate identification. All that is required is to relate referencing documents to locations (39).

If traceability is stipulated in the contract, the contractor should be able to provide trails back from a completed construction part to the sources of materials, batch and equipment used, personnel involved, and other relevant information (37). Another objective of traceability is to pinpoint the extent of the defects (39). For example if defective welds were found at a certain construction area, and the main cause was defective welding electrodes, the contractor must be able to identify the batch from which the defective electrodes were taken and to remove the remaining quantity so that the same defect will not occur in other areas.

In order to avoid problems which may be associated with the implementation of this element of the contractor's quality system, the contract must specify the level of traceability (39). This clause, however, is one of the

clauses which the FIEC's European survey report (8) classified to be of little use in construction

Clause 4.9 : Process Control

Under this clause, the standard requires the contractor to plan and control all activities that affect the quality of construction projects by (22) :

- Documenting the sequence and manner of all activities
- Using suitable and maintained construction equipment
- Identifying the acceptance criteria of construction materials and workmanship
- Qualifying personnel, procedures and equipment and special processes, as required
- Monitoring the construction activities and controlling parameters of special processes to ensure achievement of quality.

Oliver (33) commented that the standard uses the term 'process' under clause 4.9 in a narrow sense and is limited to production and installation, while the fundamental principle underlying quality management is that the 'processes'- whatever the process might be - and to the extent that quality is affected must be under control. He suggested that the clause be modified and should be put right after clause 4.2 since all the quality activities are in fact processes. Instructions

must be prepared and used for each critical construction work if its absence would adversely affect quality (40).

Equipment Maintenance

The standard requires the contractor to have a planned maintenance program of his construction equipment. Material handling equipment is also to be maintained to ensure that the items to be lifted or transported from one location to another will not be damaged (32).

Special Processes

The system should identify and document procedures for special construction processes that are distinct from the ordinary activities. The procedures must include the methods by which the processes are performed, equipment and materials used, qualification of performer, specification of environmental condition requirements, and identification of acceptance criteria.

The system must have provisions for the qualification of the performance procedures, personnel, equipment and identification of critical process parameters.

For example, welding procedures should address base materials, filler materials, joint design, preheat and post heat treatments, electrical characteristics and industry standard used (AWS, ASME, API, etc.). Level of qualification of personnel performing special processes should be based on specified requirements such as written and practical tests in accordance with a

code or standard, or demonstration in routine work that the personnel performing the activity are competent (36).

Clause 4.10 : Inspection and Testing

Under this clause, the contractor is required to (22) :

- Establish, implement and maintain documented procedures for inspection and testing
- Perform receiving inspection and testing for incoming supplies brought to the project site to verify compliance with procurement orders
- Perform in-process inspection and testing at intermediate stages (including hold points) of construction as required by the quality plan
- Perform final inspection and testing to verify acceptance of all aspects of the construction project per the quality plan
- Document the inspection and testing results and maintain the records

The main objective of the contractor's inspection and testing is to provide objective evidence that the constructed project and related components meet contract requirements. Inspection and testing activities will be performed by the contractor during all phases of the project such as receipt, storage, field fabrication, in-process, erection, and upon completion prior to handing over to client (37).

Construction quality involves two principal aspects, namely materials and workmanship. Inspection of the quality of these two aspects is very crucial in verifying the quality of the constructed project. Quality control is very important during the construction phase of projects to ensure minimum acceptable standards are met. Perception of the quality of workmanship is sometimes subjective, and the practices for determining compliance with the "minimum acceptable standards" definition are more varied than for specified characteristics. Soil compaction and tightness of bolt, are two examples of objective properties. Their minimum acceptance standards are very well defined and published in standards. However, for work where subjective judgments are involved, such as in the case of concrete finish wall, then common sense and experience will suffice (36).

It is advisable that a design engineer be responsible to outline the construction quality control and acceptance criteria of construction workmanship and materials, and even in the determination of the required qualifications of inspection personnel (25).

Inspection and Testing Procedures

Inspection and testing activities specified in the quality plan or inspection and test plan, are performed as detailed in the procedures (37). The inspection and testing procedures should specify the quantitative and qualitative acceptance criteria for construction workmanship and materials. For example,

inspection of concrete construction work includes checking the formwork system, installation of reinforcing steel and concrete quality, concrete placement and curing, form removal, repair work, core drilling, sampling and testing, weather condition requirements, foundation bedding, bonding and joining, leveling and alignment, finishing, grouting and protective coating operations (1).

Inspection and test procedures include checking the qualification of materials to be incorporated in the construction project. For example, all materials used to produce concrete, the mix proportioning, and the physical properties and hardness are to be qualified (1). The inspection and testing procedures must also address the method, type of equipment to be used, environmental conditions and the records to be filled (the inspection and test reports) (37).

Receiving Inspection and Testing

In accordance with a documented procedure and as specified in the Inspection and Test Plan (ITP), the contractor should inspect the items (materials or equipment) procured for the project when received at the job site to verify that they comply with the procurement requirements in all aspects (37).

Procured materials are manufactured products, such as structural steel, pipes, concrete, paint, electric or mechanical equipment. The contractor should have procedures that outline the level of quality and method of performing

receiving inspection (37). This also applies to semi-finished materials such as pre-cast concrete (40).

The inspection procedure should include the means for verifying and documenting whether or not the shipment is complete, identified and undamaged. The extent of the inspection and testing should depend on the history of the supplier's quality performance (36).

Clause 4.10.1.2 which allows the release of incoming product for urgent production purposes subject to immediate recall in the case of nonconformance to specified requirements, is not always applicable in the construction industry. In the case of concrete, for example, it is not possible to complete the tests before the material is incorporated into the construction work. It cannot simply be recalled. It must be dealt with as a nonconforming product (39).

In-Process Inspection and Testing

In accordance with a documented procedure and as specified in the Inspection and Test Plan (ITP), the contractor should perform in-process inspection to ensure that the construction work is being performed as required at all stages. This is especially applicable when inspection at intermediate stages is required and following construction activities would prevent this same inspection at a later stage, e.g. inspection of excavation (40), reinforcement steel and formwork prior to pouring concrete. The ITP should identify the in-process inspection by "Hold-Points" (36).

At these "Hold Points", work should not progress until inspection is performed and the work found acceptable. For example, for concreting activities, the contractor should establish adequate measures for pre-concreting (e.g. slump test), concrete placement and post concreting inspections (32). An example of "positive recall" required by the standard is in-situ concrete awaiting the results of concrete cube tests (40).

Final Inspection and Testing

In accordance with a documented procedure and as specified in the Inspection and Test Plan (ITP), the contractor should perform final inspection to ensure that the completed construction work conforms with the project requirements (36). Before handover to the client, the contractor is required to inspect and test all completed construction work, and should verify that all receiving and in-process inspections and tests required by the quality plan have been performed successfully (36).

Inspection and Test Records

Inspection and test records should be completed to document the results of the activities performed, and should (37) :

- Identify the date of inspection and test
- Specify the work or item inspected or tested
- State the acceptance criteria

- Reference the applicable document such as clause of the standard. contract specifications, or drawing number
- Identify the inspection or test performed and the results
- Include nonconformance reports (in case of partial or full rejection).

Clause 4.11 : Control of Inspection, Measuring, Inspection and Test Equipment

Under this clause, the contractor is required to (22) :

- Establish, implement and maintain documented procedures for the control and calibration the inspection, measuring and test (IMT) equipment
- Select the IMT that is capable of providing measurements with the necessary accuracy
- Identify each IMT by a unique number and affix a sticker indicating the calibration status
- Check the capability of the IMT equipment (calibration) and establish frequency of rechecking
- Calibrate and adjust the IMT equipment, under the required environmental conditions, against certified master equipment having valid traceability to international or national standards
- Store the IMT equipment safely and maintain the calibration records.

The standard requires the contractor to use proper equipment for inspection, measuring and testing to demonstrate that the various construction works are performed within the acceptance criteria specified in the project documentation (32). Examples of these equipment are surveying equipment (e.g. level, theodolites, distance measuring equipment, tapes) concrete batching plants, site laboratory equipment, etc. (40).

Clause 4.12 : Inspection and Test Status

Under this clause, the contractor is required to have means to identify the acceptability of construction items with regard to inspection and tests performed, throughout the construction process (32). This requirement cover all inspection and testing of materials, equipment or construction work (40).

The contractor should distinguish between inspected and uninspected constructed items by using suitable identification such as tags, marking or routing cards, to ensure that all items, as applicable, have been inspected satisfactorily (37). This is a safeguard against unacceptable materials being used or defective construction work being built on (40). This clause, however, has been identified by the FIEC European survey report as one of the clauses that present difficulties in their application in construction (8).

Clause 4.13 : Control of Nonconforming Product

Under this clause, the contractor is required to (22) :

- Establish, implement and maintain documented procedures for controlling construction work or materials that do not conform to contract requirements
- Identify (by marking or tagging), document and segregate (if practical) the nonconforming components
- Identify responsibility of disposition (e.g. replace, rework, repair of non-conforming items) by concerned personnel, including the customer if specified in the contract, who must have the competence to make the right decision
- Implement the disposition and verifying its effectiveness
- Document the above in the so-called "Non-Conformance Report" (NCR).

This clause is relevant to any construction activity when found non-conforming to the project specification and quality requirements such as inadequate foundation materials, incorrect type of cement or steel reinforcement (40).

Documenting the nonconformance does not only serve as a tool to track the problem areas from beginning to end, but also helps in taking corrective measures to prevent reoccurrence of these problems in the future. The historical

data developed through documenting the nonconformances which occurred during the projects can be used to reduce the costs of future projects (37).

This clause has been identified by the FIEC European survey report as one of the clauses that presents difficulties in their application in construction. This European survey showed that obtaining declaration of nonconformity is sometimes difficult to apply (8). CIRIA Special Publication 84 agreed that this clause is one of the most difficult aspects of the quality system because it requires the contractor's personnel to admit openly and to put in writing that they have done something wrong. This may cause the contractor not to notify the customer (39).

Clause 4.14 : Corrective and Preventive Action

Under this clause, the standard requires the contractor to have on-going self-examination to prevent problems related to the quality of the constructed projects. Whenever any nonconformity occurs the contractor is required to investigate the root cause of the problem and to take proper measures to prevent reoccurrence. Corrective actions and the procedures of corrective action and preventive action are to be documented (22).

Nonconformances might be due to (37) :

- Deficiencies or deviations in construction processes or related activities such as procurement

- Inadequate procedure and documentation
- Noncompliance to procedures
- Inadequate control of work
- Poor planning and scheduling

One of the most important functions of an effective quality system is to eliminate non-compliance work, and more attention must be exerted to prevent problems rather than just correcting them when they happen. The replacement or rectification of defective work or materials is far more costly than ensuring that they are correct in the first place (43). This requires on-going self examination to identify appropriate actions to eliminate potential causes of nonconformity (40). This clause has been identified by the FIEC European survey report as one of the clauses that present difficulties in their application in construction (8).

Clause 4.15 : Handling, Storage, Packaging, Preservation and Delivery

FIEC's European survey report showed that this clause has little use in construction (8). Also, CIRIA Special Publication 74 stated that this clause has less relevance to the construction industry than to manufacturing, and that it only applies to construction materials procured for the projects (40). CIRIA Special Publication 84, however, indicates that this clause may have some relevance in safeguarding materials at the project site against weather conditions (39).

Handling

Per a documented procedure, the contractor should ensure the procured materials and equipment for the project when received at the site or during construction and installation are handled properly so that their quality will not be degraded because of inappropriate handling, lifting and rigging methods. The extent of care exercised by the contractor in material handling should consider the following criteria (37) :

- Physical characteristics of the materials or equipment such as weight, size, balance point, shock damage and proximity to other constructed parts or objects
- Prevention of damage of special surface finishes from scratching and abrasion
- Prevention of adverse contact between materials, e.g. stainless steel with carbon steel
- Weather conditions which may effect or endanger the quality of the items.

Storage and Preservation

Per a documented procedure, the contractor should properly store procured items to ensure that they are preserved safely prior to use or installation in the construction project. The extent of measures taken in storing these items depends on their nature and sensitivity to the surrounding environment. The storage activities will include stocking, racking, shading,

enclosing (e.g. for PVC pipes), cushioning, cleaning, controlling temperature and humidity (e.g. for electrical and instrumentation equipment). Good housekeeping is required which will enable material handling equipment operators to do their function without damaging any stored items. Manufacturer recommendations should be followed strictly (37). The contractor should periodically check stored items for condition and shelf-life expiry, such as gaskets, o-rings and paints (32).

Packaging and Delivery

These two sub-clauses of the standard are considered not applicable to the construction industry (32).

Clause 4.16 : Control of Quality Records

Under this clause, the standard requires the contractor to (22) :

- Establish, implement and maintain documented procedures for preparing and controlling quality records
- Provide a safe filing, retention and retrieving system (that meets contractual requirements) of the quality records.

Quality records are important being documentary evidence that demonstrate the achievement of quality and effective implementation of the contractor's internal quality system (40). Quality system related quality records required by the ISO 9001 standard are listed in Table 8.

TABLE 8 : Quality Records Required by ISO 9001 (22)

Required Quality Records	Relevant ISO 9001 Clause
Management review meetings records	4.1.3
Contract review	4.3.4
Design review	4.4.6
Design verification	4.4.7
Quality records of acceptable suppliers or sub-contractors.	4.6.2 c
Unsuitable purchaser supplied product	4.7
Product or batch identification	4.8
Records of qualified processes and personnel	4.9
Urgent release of incoming product	4.10.2.3
Inspection and test records	4.10.4
Frequency of calibrating measuring and test equipment	4.11.1
Calibration records	4.11 f
Nonconformance report (NCR)	4.13
Corrective action and investigation following NCR's	4.14.2 b
Internal audits and follow up reports	4.17
Training records	4.18

Project related quality records may include (37) :

- Contract's technical documents (drawings, specifications, calculations, etc.)
- Inspection and test plan
- Inspection and test procedures and records
- Nonconformance reports
- Calibration records
- Qualification records of procedures and personnel for special processes
- As-built drawings
- Material qualification records
- Procurements documents

The contractor should have documented procedures for the storage of quality records. The procedures must state the contractor's ordinary retention period of the quality records which may be overruled by the contract requirements. Usually the retention period is 10 years. Records must be easily retrievable whenever needed (32).

Clause 4.17 : Internal Quality Audits

Under this clause, the standard requires the contractor to (22) :

- Plan and schedule internal quality audits
- Perform internal quality audits by independent personnel
- Discuss the results of internal audits with the audited departments and issue the so-called Corrective Action Requests (CAR'S), if needed
- Follow up on performed internal audits to verify corrective action implementation and adequacy
- Establish, implement and maintain documented procedures for internal quality audits and maintain records of audits and follow up reports.

This clause probably is the most important clause in the standard since the internal quality audits verify whether or not the quality system is functioning effectively (40). The Internal quality audit is an essential part of the quality assurance system to be used as a means by which the contractor's management

can assess its performance in terms of identifying its strengths and weaknesses and required remedies (45).

The contractor's quality system is required to undergo regular and comprehensive auditing program to verify implementation and evaluate adequacy. This will cover all areas and processes in the construction company. The audits are to be scheduled based on the importance of their functions. The internal audit should be performed in accordance with a documented procedure. The documented procedure will cover preparation of the internal audit schedule and notification to the auditee, performance and reporting of the internal audits, issue of corrective action requests and follow up (40).

The results of the internal audits must be documented and presented to management of the audited departments for timely corrective action of any nonconformances found, and must be followed-up to verify effectiveness of corrective actions taken (42).

Clause 4.18 : Training

Under this clause, the standard requires the contractor to (22) :

- Identify training needs for all personnel whose assigned activities affect quality of construction, and provide this needed training

- Qualify the personnel performing specific assigned tasks based on education, training and experience
- Establish, implement and maintain documented procedures for training
- Maintain records of training and qualification of personnel

The success of the quality system of any contractor depends significantly on the availability and employment of appropriately trained and experienced personnel (39). The standard emphasizes on formal training program that focuses on identifying individual training needs based on appropriate task analysis, and ensures that every worker (23) :

- Understands and knows how to perform the processes involved in his job correctly, and that he is very well familiar on how to use the tools (equipment, software, etc.) in these processes
- Understand the extent and sources of variability in those processes, and the degree he has control over that variability
- Understand the quality standards (acceptance criteria) required for his job.

The contractor should establish standardized means to assure objective evaluation of personnel competence including education, experience and technical qualifications. Performance of personnel should be observed and monitored. If it is found that the individual capability does not meet the minimum level of competence, the contractor must take all necessary measures to correct the situation which may include providing additional training, or even replacement (37).

Clause 4.19 : Servicing

This after-sales servicing clause might not be applicable unless specified in the contract. In order to maintain the quality of the constructed project, it is recommended that contractor issue instructions or guidance to the owner on post-completion needs, such as required periodic inspection, painting and clearance of drainage outlets (39). FIEC's European survey report showed that this clause has little use in construction (8).

Clause 4.20 : Statistical Techniques

Under this clause, the contractor is required to identify his need for statistical techniques, and to establish and implement documented procedures for the application of these techniques. The standard defines the purpose of statistical technique as being "required for establishing, controlling and verifying process capability and product characteristics" (22).

CIRIA Special Publication 84, however, states that this clause has little relevance to construction since most construction projects are one-off while the clause is mainly relevant to mass production (40). This is also supported by the FIEC's European survey report (8).

However, limited applications of statistical techniques in construction might include sampling materials delivered at the project site, such as cement and aggregate for concrete, and repetitive use of the same design, such as concrete cube testing (40).

2.2.8 Implementation of ISO 9000 in Construction Industry Around The World

There has been much difficulty in finding sufficient literature that deals with the implementation of ISO 9000 standard in construction around the world. Most of this literature are general and do not talk about construction specifically. The following is a summary of the literature obtained that covers this subject.

2.2.8.1 Australia

The Joint Accreditation Scheme for Australia and New Zealand (JAS-ANZ) have accredited 17 third party certifying bodies in Australia. These certification bodies has certified about 12000 companies (all types of companies) in Australia and New Zealand. (This information has been obtained from the "Standard Australia" through fax).

The Australian National Building Code does not refer to the AS 3900 (national standard equivalent to ISO 9000) or to any quality system requirements. Large public contracts, however, such as power generation, road and dam construction projects, specify the quality assurance requirement. The demand on contractor's quality system is increasing (41).

2.2.8.2 Europe

In Europe, the European Construction Industry Federation (FIEC) conducted a survey in 1993 to evaluated the extent to which quality

management system standard (ISO 9000) are being adopted by the construction sector.

The FIEC report (7) stated that the construction sector is dragging its feet over ISO 9000 registration and lags behind other sectors, especially manufacturing, in this respect. Many construction organizations are reported to reject ISO 9000 as only being relevant to the manufacturing industry.

FIEC conducted another survey in 1995 which showed some progress (see Table 9). The total number has been increased from 263 in 1993 to 805 in 1995. As can be seen from Table 9, with the exception of Czech Republic and Sweden, the number of construction companies that are certified to ISO 9000 standard has been increased in all countries.

According to the 1993 survey, the number of certified construction organization is very low compared to manufacturing. For example, the report revealed that only 263 out of 1.8 million construction enterprises in Europe (0.015 %) have been certified to ISO 9000 standard. The 1995 survey did not mention the total number of construction enterprises. Assuming the number of construction companies in Europe has stayed the same (1.8 million), the percentage of certified construction organizations in Europe has become 0.044 %.

2.2.8.2 Singapore

Quality Assurance is still relatively new concept in the Singapore construction industry. By 1994, only four construction related organizations had been certified to ISO 9000 standard. Two of these are private companies and two public organizations (Structural Engineering Department of Housing and Development Board and the Public Works Department) (34).

TABLE 9 : Number of European Construction Companies Certified to ISO 9000 Standards (7,8)

Country	No. of certified construction Companies in 1993 (7)	No. of certified construction Companies in 1995 (8)
Austria	*	15
Belgium	0	60
Czech Rep.	79	20
Denmark	10	27
Finland	2	4
France	5	41
Germany	30	150
UK	95	130
Ireland	25	120
Italy	5	10
Luxembourg	1	2
Netherlands	10	130
Portugal	0	1
Spain	0	15
Sweden	1	0
Switzerland	0	80
TOTAL	263	805

(*) Was not covered in the 1993 study.

2.2.8.3 USA

In 1987, the American National Standards Institute (ANSI) and the American Society of Quality Control (ASQC) adopted the ISO 9000 series of standard and designated as ANSI/ASQC Q90. There are approximately twenty

registrars for the Q90 standards. There is an increasing number of government agencies and industrial clients requiring contractors bidding for construction projects to operate quality programs.

In 1994, for the first time, a construction company received the Malcolm Baldrige National Quality Award (MBNQA). The MBNQA is an annual award that is given to US companies that are most successful in quality management and quality achievement (41).

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter explains the method used to achieve the objectives of this study, i.e. analyzing the quality systems of fifteen construction contractors in the Eastern Province which were selected for the assessment of their quality systems against the ISO 9000 standard.

3.2 Population

The population of the case studies are construction contractors which were selected based on the recommendations of the Eastern Province Chamber of Commerce. These contractors are classified among the first two classes in the current classification of the Chamber of Commerce. They are of large size and involved in large projects.

To begin with, thirty-four contractors were identified by the Chamber of Commerce and the contractors were screened, bringing the number down to fifteen. All contractors were contacted either by fax or by phone to ensure their willingness for participation. The screening process excluded the contractors who either declined to participate in the study because they were busy with current projects and preparing for bids, or because the concerned personnel were not available. An other group of contractors could not be included in the study because they either changed their location outside the Eastern Province or ceased work in construction. Table 10 provides background information about the selected contractors by identifying their location, years of experience in construction business, number of employees, construction activities and major clients. The table also identifies the position of the contractor's representatives who were interviewed during the visits to the companies.

3.3 Data Collection

This study is an explanatory type of research to assess the quality systems of fifteen contractors. The fifteen construction contractors were visited and their delegated personnel were interviewed to obtain the needed information regarding their quality systems. All interviews included key individuals from the contractors management (see Table 10). Each interview took between 2 to 4 hours, and some interviews were done in two parts. It was very difficult for the company representatives to allocate the needed time for the interview.

TABLE 10 : Background Information About the Contractors Included in the Study

Contractor No.	Location	Years in Business	No. of Employees	Construction Type	Major Clients	Position of Contacted Person
1	Khobar	4	700	Electrical, piping, piping mechanical, structural steel,	S. Aramco	General Manager
2	Raheemah	35	6346	Civil, Structural steel, piping Mechanical, Electrical	S. Aramco	QA Manager
3	Dammam	34	1000	Mechanical, electrical, civil	S. Aramco	QA/QC Engineer
4	Khobar	23	80	Reinforced concrete, steel work	SABIC	Projects Manager
5	Dammam	40	4000	Petrochemical, refining, desalination, process control	S. Aramco SABIC	QA/QC Manager
6	Khobar	49	1000	Roads, civil	Ministry of Defense	Business Development Manager
7	Khobar	16	2100	Buildings, mechanical, electrical, HVAC	S. Aramco	QA Manager
8	Dammam	25	1000	Mechanical, electrical, instrumentation	S. Aramco SCECO, SABIC	QC Manager
9	Khobar	5	450	Mechanical, piping, tanks	SCECO, SABIC	Business Development Manager
10	Dammam	35	1500	Buildings (schools)	S. Aramco	Operations Engineer
11	Dammam	17	475	Building, civil	SABIC	Projects Manager
12	Dammam	20	600	Mechanical, electrical, civil	S. Aramco	Purchasing and Projects Managers
13	Khobar	8	3000	Buildings, structural steel	Internal only	QC Manager
14	Dammam	40+	2500	Mechanical, electrical, civil	S. Aramco SABIC	Procurement Manager
15	Khobar	29	425	Roads, sewer	S. Aramco Royal Commission	Projects Manager

The method of face-to-face interview was preferred over mailing the survey Questionnaire to the contractor in order to expedite obtaining the responses and to clarify the questions, if needed.

The survey questionnaire exhibited in Appendix (A) was used during these interviews as a checklist, and completed to document the contractors' answers. This survey questionnaire consists of two parts. The first part of the questionnaire is general and intended to get information about the contractors general interest in and perspective towards the ISO 9000 standard, i.e. to know their familiarity, implementation experience, and status of certification or plans to be certified to ISO 9000 standard. The second part of the questionnaire, on the other hand, consists of specific questions regarding the requirements of the ISO 9000 clauses. This part of the questionnaire was intended to get information about the various elements of contractors quality systems, and to determine whether or not the contractors have existing, documented and implemented systems that meet the requirements called for by the ISO 9001 clauses (except clause 4.19 " servicing" which was not covered by the questionnaire, as mentioned in the proposal). Every contractor was asked if he has an existing means in their quality system that satisfy each ISO 9001 clause, and if these means are documented and implemented.

3.4 Data Analysis :

Upon completion of the interviews with the contractors representatives, the data collected was analyzed per the following procedure :

3.4.1 Contractor's General Perspective Towards the ISO 9000 Standard

3.4.1.1 Familiarity with ISO 9000 Standard

The contractors will be classified according to their level of familiarity with the ISO 9000 standard into the following three categories :

- Fully familiar : Contractors who have high level of knowledge of the ISO 9000 standard and all of its requirements.
- Partially Familiar : Contractors who have some knowledge about the ISO 9000 standard and its requirements.
- Not Familiar : Contractors who have no knowledge about the ISO 9000 standard.

3.4.1.2 Certification to ISO 9000 Standard

With regard to the question of certification to ISO 9000 standard, the contractors will be classified into the following categories :

- Certified to ISO 9000 : Contractors whose quality system have been already certified by third party.

- Preparing for Certification : Contractors who were. at the time of the survey. in the process of preparing for certification of their quality system by third party to ISO 9000 standard.
- Interested in certification but not yet started preparation : Contractors who have the ambition and interest to achieve certification of their quality systems, however they did not started the actual process of preparation. In other words, it is in their long term plans.
- Not interested to be certified : Contractors who have no ambition or interest to achieve certification of their quality systems.

3.4.1.3 Applicability and Benefits of ISO 9000

Based on the data obtained from the contractors. This part identifies the contractors opinions to whether or not the ISO 9000 is applicable and beneficial to the construction industry. This part will specify any clauses of the standard which are thought to be irrelevant to the construction industry.

3.4.1.4 Difficulty of ISO 9000 Requirements

This part will identify any requirements of the ISO 9000 standard that the contractors implementing the standard had difficulties with.

3.4.1.5 Implementation Obstacles

In this part, the obstacles which the contractors faced that discouraged successful implementation of the ISO 9000 standard in their companies will be reported.

3.4.1.6 Reasons Behind Adopting ISO 9000

The internal and external motive factors behind the interest of the contractors in ISO 9000 standard will be identified.

3.4.2 Contractors Quality System Elements and ISO 9000 Clauses

The data collected using the second part of the Questionnaire was intended to get information about the various elements of contractors quality systems, and to examine whether the contractors have existing, documented and implemented systems that meet the requirements called for by the ISO 9001 clauses (except clause 4.19 " servicing" as mentioned earlier). Every contractor was asked if he has an existing means in their quality system that satisfy each of the ISO 9001 clauses, and whether these means are documented and implemented.

When this second part of the study was completed, contractor responses were recorded and analyzed. To give a quantitative measure of the extent of contractors compliance with the requirements of ISO 9001 standard, contractors input was evaluated and rated per the following criteria :

- Contractors who have systems that fully comply with the respective clauses of the ISO 9001 standard were rated as "Y" (value = 1.0 point).

- Contractors who have systems that partially comply with the respective clauses of the ISO 9001 standard were rated as "NF" (value = 0.5 point).

- Contractor's systems that did not meet the requirement of the standard were rated as "N" (value = 0 points). If the standard did not apply to them, they were rated as "NA" (value = 0 points).

For each clause, the three aspects (i.e. "Existing", "Documented" and "Implemented") were totaled based on this rating system. The percentages of compliance will be found using the following formula :

Percentage = (Total / 15) * 100

The information obtained will be entered in the following tabular presentation :

		Companies																
ISO 9000 Clauses		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	%
4.1	Exist																	
	Documented																	
	Implemented																	
. . . .																		
4.20	Exist																	
	Documented																	
	Implemented																	

To illustrate this idea, the following is a hypothetical situation :

Example :

Suppose that during the survey of contractor 1, the following information was found about his compliance with the requirements of clause 4.17 (internal quality audits) of ISO 9001 :

If contractor 1 has a system of scheduling and performing internal quality audits, this will be rated "Y". If it was found that contractor 1 does have any documented procedure for internal audits, this will be marked as "N. Finally, if contractor 1 performs some of the scheduled internal quality audits and does not document the audit findings, this will be rated as "NF". These ratings will be entered in the table as shown below.

		Companies																
ISO 9000 Clauses		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total	%
. . .																		
4.17	Exist	Y																
	Documented	NF																
	Implemented	N																
. . .																		

The same method will be applied with other contractors for other clauses of the standard.

Then, the findings of this part will be discussed, and the ranking of the ISO 9001 clauses (based on the calculated Percentage of compliance by the

contractors) will be given in terms of the three aspects (existence of the system, implementation and documentation). This discussion will highlight the significant observations found about any element of the contractors quality system.

Most of the data analysis will be provided in a tabular form (see Chapter 4).

CHAPTER 4

FINDINGS AND DISCUSSIONS

4.1 Findings :

4.1.1 Contractors' General Perspective Towards the ISO 9000 Standard

The contractors' answers to the questions contained in the first part of the questionnaire have been used to measure the contractors' general perspective about the ISO 9000 standard. The contractors responses are presented in the following paragraphs.

4.1.1.1 Familiarity with ISO 9000 Standard

As can be seen from Table 11, six contractors said that they are fully familiar with the ISO 9000 standard while six other contractors are partially familiar with it. Three contractors, however, are not familiar with the subject standard.

TABLE 11 : **Contractors' Familiarity with ISO 9000 Standard**

Familiarity with ISO 9000 Standard	Contractors															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Fully familiar	X	X			X		X	X						X		6
Partially familiar			X			X			X	X		X	X			6
Not familiar				X							X				X	3

4.1.1.2 Certification to ISO 9000 Standard

The survey revealed that two out of the fifteen contractors who were included in this study have already certified their quality systems to ISO 9002-1994 standard (as can be seen from Table 12). These are :

- Mohammad Al-Mojil Group, Construction Division (certified by ABS Quality Evaluation Ltd., certified since 26 June 1995)
- Mohammad Salem Al-Suwaidi Establishment for Contracting (certified by SGS Yarsley International Certification Services Ltd. on 24 April 1996).

In addition, there are four contractors are planning to be certified in the near future; three of them have hired external consultants to assist in the process of establishing formal quality systems in their organizations and preparing for certification thereafter. The other four contractors are interested to be certified but not in the near future (see Table 12).

TABLE 12 : Summary of Contractors Status of Implementation and Certification of Their Quality Systems to the ISO 9000 Standard

Status of certification to ISO 9000 Standard	Contractors															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Claim compliance with ISO	X	X	X		X			X		X				X		7
Certified to ISO 9000		X			X											2
Preparing for certification							X	X					X	X		4
Interested in certification but not yet started preparations	X					X			X	X						4
Not interested to be certified			X									X				2
No comment (not familiar)				X							X				X	3

4.1.1.3 Applicability and Benefits of ISO 9000

As can be seen from Table 13, ten contractors believe that the ISO 9000 standard is applicable to the construction industry and will be beneficial for their companies. These contractors made no exception to any of the clauses of the standard. On the other hand, the three contractors which are not familiar with the ISO 9000 standard made no comment while two contractors mentioned that time will prove whether or not, the ISO 9000 standard is applicable in construction. Two contractors have some reservations about the added value of the standard to the quality of construction projects.

TABLE 13 : Contractors' Viewpoint Regarding the Applicability and Beneficiary of the ISO 9000 Standard

Applicability of ISO 9000 Standard in Construction	Contractors															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Applicable and beneficial	X	X	X		X	X	X	X	X	X			X			10
Have reservation												X		X		2
No comment (not familiar)				X							X				X	3

4.1.1.4 Difficulty of ISO 9000 Requirements

Six contractors responded that the ISO 9000 standard is not difficult to implement while other six contractors said the opposite. The remaining three contractors who are not familiar with the standard were not able to comment on this question (see Table 14).

TABLE 14 : Contractors Opinion About the Difficulty of the ISO 9000 Standard

Difficulty of ISO 9000	Contractors															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Difficult	X	X			X			X				X	X			6
Not Difficult			X			X	X		X	X				X		6
No comment (not familiar)				X							X	X			X	3

The difficulties in implementing ISO 9000 that have been identified by the respondents included :

- Voluminous amount of required paper work associated with the documentation of the quality system and its implementation
- Difficulty in controlling the sub-contractors
- Difficulty in full implementation of all of the requirements, and the possibility of deviating sometimes
- Difficulty in understanding the terminology of the standard.

4.1.1.5 Implementation Obstacles

Ten contractors have identified various obstacles that discourage successful implementation of the ISO 9000 standard in their companies. The obstacles identified by these ten contractors are included in Table 15.

TABLE 15 : Obstacles Identified by the Contractors Who Are Implementing or Intend to Implement Quality Systems That Comply with ISO 9000

Obstacles	Contractors															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
High cost; especially initial cost	X					X						X		X		4
Resistance to change at various levels in the organization					X			X					X	X		4
Loss of productivity of the workforce due to the effort exerted in learning the new system and implementation, besides their regular duties							X			X						2
Management interference														X		1
Limited ability of personnel								X								1
Remote job sites which makes it hard to control and track the quality system implementation in all sites									X							1
Communication problems between personnel because of the language differences							X									1
Cultural differences between the workforce							X									1
No obstacles		X	X													2
No comment (not familiar)				X							X				X	3

Only two contractors responded that there are no obstacles that discourage successful implementation of the ISO 9000 standard in their companies, while the three contractors who are not familiar with the standard made no comment.

4.1.1.6 Reasons Behind Adopting ISO 9000

The contractors were asked about the motive behind their interest in ISO 9000 standard. Their feedback is indicated in Table 16. The contractors who adopted the ISO 9000 standard answered that they have done so because of management interest being beneficial in improving the quality of their construction projects, or because of current or expected demand from customers. The later group of contractors felt that it is going to be compulsory in the future for public and private contracts. One contractor (no. 14) said that he wanted to be ahead of others when certification to ISO 9000 becomes a prerequisite for acceptance of bids. Three contractors advised that their largest clients, namely : Saudi Aramco, SABIC companies and the Ministry of Defense and Aviation (MODA), have required them to operate quality assurance systems that meet the ISO 9000 standard.

TABLE 16 : Reasons Behind Adopting ISO 9000 Standard

Reasons behind adopting ISO 9000 standard	Contractors															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Management initiative	X	X			X								X			4
Customer requirement			X		X			X								3
Expected demand in the future	X						X							X		3
No demand				X		X			X	X	X	X			X	7

4.1.2 Contractors Quality System Elements and ISO 9000 Clauses

Table 17 summarizes the percentage of compliance of the contractors quality systems with the ISO 9001 clauses.

TABLE 17 : Contractors' Compliance with ISO 9001 Clauses

ISO 9001 Clauses		Contractors															Total	%
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15		
4.1	Exist	Y	Y	NF	N	Y	N	Y	NF	NF	Y	NF	N	NF	N	N	7.5	50
	Documented	Y	Y	NF	N	Y	N	Y	NF	NF	Y	N	N	N	N	N	5.5	43
	implemented	Y	Y	NF	N	Y	N	Y	NF	NF	Y	NF	N	NF	N	N	7.5	50
4.2	Exist	Y	Y	NF	N	Y	NF	NF	NF	Y	NF	NF	NF	NF	NF	NF	9	60
	Documented	Y	Y	NF	N	Y	NF	NF	NF	Y	NF	NF	NF	NF	NF	NF	9	60
	Implemented	Y	Y	NF	N	Y	NF	NF	Y	Y	NF	NF	NF	NF	NF	NF	9	60
4.3	Exist	Y	Y	Y	Y	Y	Y	Y	NF	Y	Y	Y	Y	Y	Y	Y	14.5	97
	Documented	Y	Y	N	N	Y	N	Y	N	Y	N	N	N	Y	N	N	6	40
	Implemented	Y	Y	Y	Y	Y	Y	NF	NF	Y	Y	Y	Y	Y	NF	Y	13.5	90
4.4	Exist	NA	NA	NA	NA	NA	NA	NF	NA	NA	NA	Y	NA	Y	NA	Y	3.5	23
	Documented	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	N	NA	N	NA	N	0	0
	Implemented	NA	NA	NA	NA	NA	NA	NF	NA	NA	NA	Y	NA	Y	NA	Y	3.5	23
4.5	Exist	Y	Y	NF	NF	Y	Y	NF	NF	NF	NF	NF	Y	Y	Y	NF	11	73
	Documented	Y	Y	Y	N	Y	N	NF	NF	NF	N	N	N	NF	Y	N	7	47
	Implemented	Y	Y	NF	NF	Y	Y	NF	NF	NF	NF	NF	Y	NF	NF	NF	10	67
4.6	Exist	N	Y	NF	NF	Y	NF	N	Y	NF	Y	Y	NF	N	NF	NF	8.5	57
	Documented	N	Y	N	N	Y	N	N	Y	N	Y	Y	N	N	NF	NF	6	40
	Implemented	N	Y	NF	NF	Y	NF	N	NF	NF	Y	Y	NF	N	NF	NF	8	53
4.7	Exist	Y	Y	Y	N	Y	Y	NA	Y	Y	Y	NA	NF	NA	Y	NA	9.5	63
	Documented	Y	Y	Y	N	Y	N	NA	Y	Y	N	NA	N	NA	Y	NA	7	47
	Implemented	Y	Y	Y	N	Y	Y	NA	Y	Y	Y	NA	NF	NA	Y	NA	9.5	63
4.8	Exist	Y	Y	Y	N	Y	Y	NF	Y	Y	Y	N	N	NF	Y	N	10	67
	Documented	Y	Y	Y	N	Y	N	NF	Y	Y	N	N	N	N	Y	N	7.5	50
	Implemented	Y	Y	Y	N	Y	Y	NF	Y	Y	Y	N	N	NF	Y	N	10	67
4.9	Exist	Y	Y	Y	NF	Y	Y	Y	NF	Y	Y	Y	Y	NF	NF	Y	13	87
	Documented	Y	Y	Y	NF	Y	N	Y	NF	N	Y	NF	N	N	NF	Y	9	60
	Implemented	Y	Y	Y	NF	Y	Y	Y	NF	NF	Y	Y	Y	NF	NF	Y	12.5	83
4.10	Exist	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NF	Y	Y	14.5	97
	Documented	Y	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	N	Y	Y	12	80
	Implemented	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NF	Y	Y	14.5	97
4.11	Exist	Y	Y	Y	Y	Y	NF	Y	Y	Y	Y	Y	Y	N	Y	Y	13.5	90
	Documented	Y	Y	Y	N	Y	N	NF	Y	N	Y	N	N	N	NF	N	7	47
	Implemented	Y	Y	Y	Y	Y	NF	Y	Y	Y	Y	Y	NF	N	Y	Y	13	87
4.12	Exist	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NF	Y	Y	14.5	97
	Documented	Y	Y	Y	N	Y	N	Y	Y	Y	Y	Y	Y	NF	Y	Y	12.5	83
	Implemented	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	NF	Y	Y	14.5	97
4.13	Exist	Y	Y	Y	NF	Y	Y	NF	Y	Y	Y	Y	Y	Y	Y	Y	14	93
	Documented	Y	Y	Y	N	Y	N	N	Y	N	NF	Y	Y	Y	Y	Y	10.5	70
	Implemented	Y	Y	NF	NF	Y	Y	NF	Y	Y	NF	Y	Y	Y	Y	Y	13	87
4.14	Exist	Y	Y	N	N	Y	NF	N	Y	NF	Y	N	NF	N	Y	N	7.5	50
	Documented	Y	Y	N	N	Y	N	N	N	Y	Y	N	N	N	Y	N	6	40
	Implemented	N	Y	N	N	Y	NF	N	Y	NF	Y	N	NF	N	Y	N	6.5	43
4.15	Exist	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	15	100
	Documented	Y	Y	N	N	Y	N	N	Y	Y	N	Y	N	N	Y	Y	8.5	53
	Implemented	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	15	100
4.16	Exist	Y	Y	Y	Y	Y	Y	Y	NF	NF	Y	NF	Y	NF	Y	NF	12.5	83
	Documented	Y	Y	NF	N	Y	N	N	NF	NF	Y	NF	N	NF	Y	NF	8	53
	Implemented	Y	Y	Y	Y	Y	N	Y	NF	NF	Y	NF	Y	NF	Y	NF	12.5	83
4.17	Exist	N	Y	NF	N	Y	N	N	NF	N	N	N	N	N	N	N	3	20
	Documented	N	Y	NF	N	Y	N	N	NF	N	N	N	N	N	N	N	3	20
	Implemented	N	Y	NF	N	Y	N	N	NF	N	N	N	N	N	N	N	3	20
4.18	Exist	N	Y	Y	NF	Y	NF	N	NF	Y	Y	Y	N	NF	N	NF	8.5	57
	Documented	N	Y	N	N	Y	N	N	N	Y	N	N	N	N	N	N	3	20
	Implemented	N	Y	Y	NF	NF	NF	N	NF	Y	Y	Y	N	NF	N	NF	7.5	50
4.20	Exist	Y	Y	N	N	Y	N	N	Y	Y	Y	N	N	N	N	N	6	40
	Documented	Y	Y	N	N	Y	N	N	N	N	N	N	N	N	N	N	6	40
	Implemented	Y	Y	N	N	Y	N	N	Y	Y	Y	N	N	N	N	N	6	40
	Total	44.0	54.0	36.5	17.5	53.5	24.5	27.5	39.0	39.0	40.5	31.5	25.0	21.5	34.0	27.5		

Y: Yes (Comply with the Standard); Y=1.0
NF: Not Fully (Partially comply with the standard); NF = 0.5
N : No (Does not comply with the standard); N=0.0
NA : Not Applicable; NA = 0.0

The following are some of the findings pointed out regarding some aspects of the contractors quality systems :

Quality systems :

As can be seen from Table 18, only four contractors have comprehensive, corporate documented quality systems. The system of these four contractors is documented in quality manuals and procedures. Ten out of the fifteen contractors have limited project-wide quality control systems. In other words, the quality system in these companies covers only the activities associated with certain projects at the job site. These contractors do not have comprehensive, corporate (company-wide) quality assurance systems that cover all departments including the head office. Hence, they do not have installed continuos improvement systems that can benefit from the problems that took place in the past. This type of limited quality system concentrates heavily on inspection and testing. One contractor, however, has no formal quality assurance and quality control system. Construction work is checked by the project manager only.

TABLE 18 : Classification of the Contractors' Levels of Quality Systems

Contractors' Quality Systems	Contractors															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Quality manual and procedures	X	X			X				X							4
Projects related quality control plans only			X			X	X	X		X	X	X	X	X	X	10
No QA/QC system				X												1

Interviews with the contractors representatives revealed that the following limitations in their quality system elements exist :

Contract review :

Five contractors no. 7, 8, 10, 12 and 14 advised that they had encountered problems during the execution of the projects due to improper initial reviews of the project contracts. This inadequate contract review caused financial losses because of under-estimated or over-estimated bidding, and delayed projects completion due to the contractor's inability to plan for meeting contract requirements.

Document and Data Control :

It was found that eight of the contractors (see Table 19) suffered problems caused by using obsolete drawings in previous construction projects. This caused work rejection and delays in project schedules.

TABLE 19 : Contractors Who Had Problems Associated With Improper Control of Projects Drawings

	Contractors															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Obsolete drawings were used	X						X	X	X	X			X	X	X	8
No problem on obsolete drawings		X	X	X	X	X					X	X				7

Purchasing :

It was apparent from the interviews that contractors lack in implementing systems of selection and control of sub-contractors and material suppliers based on quality system basis. As mentioned in Table 20 , only five contractors prequalify their sub-contractors or suppliers. The selection process emphasize on financial aspects much more than on quality aspects. There is inadequate recording and tracking of the performance of sub-contractors and material suppliers, which is part of quality records required by the standard. Only three contractors are complying with this requirement.

TABLE 20 : Contractors Systems to Control Suppliers / Sub-Contractors

Control of Subcontractors Material Suppliers	Contractors															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Have a prequalification system	X	X	X		X								X		X	6
Their performance is recorded and analyzed		X			X			X								3
No formal system of prequalification and measurement of their performance				X		X	X		X	X	X	X		X		8

Control of Measuring, Inspection and Test Equipment :

Ten contractors claimed that they calibrate their measuring and test equipment. Five contractors advised that they do not have systems to periodically calibrate their measuring inspection and test equipment. Uncalibrated equipment were used in their construction projects (see Table 21).

TABLE 21 : **Contractors Systems of Calibrating the Measuring, Inspection and Test Equipment**

Equipment calibration	Contractors															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Equipment is calibrated	X	X	X		X		X		X	X	X			X	X	10
Used uncalibrated measuring, inspection and test equipment				X		X		X				X	X			5

Control of Non-Conforming Product :

Two contractors (no. 3 and 9) admitted that nonconformance reports issued by Quality Control personnel are sometimes ignored or overruled by project engineers. This is due to the lack of authorities given to the QC personnel (ISO 9001, clause 4.1.2). Four contractors (no. 4, 6, 7 and 9) advised that nonconformances are not documented. Contractor no. 5 revealed difficulty in implementing this clause (i.e. 4.13) sometimes because of the fear that the persons who caused the nonconformances would be affected.

Contractor no. 7 relates the cost of quality with the nonconformance. Whenever a Nonconformance report (NCR) is issued and the disposition is agreed upon, the value of the problem (i.e. the cost of rework, replacement, project delay, etc.) is calculated and documented on the NCR. This is a good practice which makes the importance of preventing problems before they occur and at least when the problems do occur the importance of taking corrective measures to prevent their reoccurrence (ISO 9001, clause 4.14).

Corrective Action :

Eleven contractors advised that formal corrective action is not done giving the chance for previous problems to reoccur (see Table 22). Interviews with the contractor representatives revealed that there is a misunderstanding about the difference between nonconformance disposition and corrective action (ISO 9001, clause 4.13 and 4.14, respectively). Many think they are the same while, by ISO 9000 standard terminology, they are different. Whenever a non-conforming work is constructed or wrong equipment is installed in the job site, a decision is made to do something about it (disposition) to solve the problem. However, no measures are taken to prevent reoccurrence of the non-conformance in the future (corrective action).

For example, suppose that contractor's QC inspector found that the layout of the underground utility pipes is not conforming with the project drawing. Accordingly, the inspector documented a non-conformance report and issued it to the project engineer who accepted the finding and decided to change the layout of the pipe work and so that it will meet the approved drawing. This decision (rework) is the disposition, not the corrective action. The corrective action would require investigation to find the root cause to prevent reoccurrence of the nonconformity. For example, if the investigation revealed that the problem happened because an obsolete copy of the drawing was used, a possible corrective action would be to modify the document control procedure so that if a revised drawing is issued, listed holders of the specific drawing would be notified

and asked to destroy the old (obsolete) drawing and replace it by the new (revised) one.

TABLE 22 : Contractors Application Of Corrective Actions

Corrective action	Contractors															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Performed		X			X				X			X		X		5
Not performed	X		X	X		X	X	X		X	X		X		X	10

Internal Audits :

As can be seen from Table 23, eleven contractors do not perform internal quality audits in their companies. Two contractors perform limited internal audits at project sites only. Internal quality auditing of the other two contractors covers not only the job sites but also all other functions within their organizations. As expected, these two contractors are the ones whose quality system have been certified to ISO 9002 standard. Representatives of both contractors mentioned that they had difficulties in implementing the internal audits. It was advised that this element of the quality system is sensitive because the audited departments were looking to audits as a way of criticism. However, it was advised by these contractors that the situation has improved since the departments have gotten used to it and the internal auditors have gained more experience.

TABLE 23 : Contractors Internal Quality Audits

Internal Quality Audits	Contractors															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Comprehensive audits		X			X											2
Limited project-wide audits			X					X								2
No audit performed	X			X		X	X		X	X	X	X	X	X	X	11

The objective of Internal quality audit must be, according to ISO 9000 standard, to verify implementation and to evaluate effectiveness. In other words, the auditor must not only check if the quality procedures are adhered to or not, but also to check if the procedures are adequate and efficient to achieve quality and assurance of quality. The contractors are generally lacking in the area of evaluating the effectiveness.

Training :

Five contractors advised that no training is provided to their employees while other eight contractors provide informal on-the-job training for their employees. Ten contractors do not have systems that identify training needs and continuos training programs (see Table 24). Training is not a priority for most contractors. Two contractors (no. 12 and 14) stated that their companies are not "training institutes", and training is costly and cannot be provided to their employees.

Contractor no. 5 provides a quality assurance introductory training for new employees and examines them (written exam) to make sure the contractor's ISO 9002-based quality system is understood. This contractor also examine the new employee to ensure that he is qualified in his trade. The exam is two parts (written and practical). Those who could not show sufficient competence are downgraded to a job that does not require skills (e.g. helper). Both contractors

no. 2 and 5 have sent their internal quality auditors for formal training courses. Contractor 2 provides internal training for the welders and cable splicing personnel, which are considered special processes (Clause 4.9) and require high level of qualification

TABLE 24 : Types of Training Provided by the Contractors to Their Staff

Type of Training	Contractors															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Formal training provided		X			X											2
Informal on-the-job training			X	X		X		X		X	X		X		X	8
Training needs identified		X			X	X				X						4
No training provided	X						X		X			X		X		5

Statistical Techniques :

Seven contractors advised that statistical techniques are not applicable to their type of business. An other six contractors said that it is applied for measuring the productivity of their construction groups. One contractor applies it for receiving inspection and another contractor uses it for evaluating the effectiveness of welding procedures (see Table 25).

TABLE 25 : Contractors Applications Of Technical Techniques

Type of Application	Contractors															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Productivity Measure	X						X	X	X	X		X				6
Welding Procedures					X											1
Receiving Inspection		X														1
No Application			X	X		X					X		X	X	X	7

4.2 Discussion :

Based on the results included in Table 17, the ranking of the compliance of contractors quality systems with the ISO 9001 clauses is shown in Table 26.

TABLE 26 : Ranking of ISO 9001 Clauses That the Contractors Use, Document and Implement

ISO 9001 Clauses	Existence of the Clause		Documentation of the Clause		Implementation of the Clause	
	Rank	Score	Rank	Score	Rank	Score
4.1 Management Responsibility	15	7.5	12	6.5	14	7.5
4.2 Quality System	12	9	4	9	12	9
4.3 Contract Review	2	14.5	13	6	4	13.5
4.4 Design Control	18	3	19	0	18	3
4.5 Document and data Control	9	11	9	7	9	10
4.6 Purchasing	13	8.5	13	6	13	8
4.7 Control of Customer Supplied Product	11	9.5	9	7	11	9.5
4.8 Product Identification and Traceability	10	10	8	7.5	9	10
4.9 Process Control	7	13	4	9	7	12.5
4.10 Inspection and Testing	2	14.5	2	12	2	14.5
4.11 Control of Inspection, Measuring and Test Equipment	6	13.5	9	7	5	13
4.12 Inspection and Test Status	2	14.5	1	12.5	2	14.5
4.13 Control of Nonconforming Product	5	14	3	10.5	5	13
4.14 Corrective and Preventive Action	15	7.5	13	6	16	6.5
4.15 Handling, Storage, Packaging, Preservation and Delivery	1	15	6	8.5	1	15
4.16 Control of Quality Records	8	12.5	7	8	7	12.5
4.17 Internal Quality Audits	18	3	17	3	18	3
4.18 Training	13	8.5	17	3	14	7.5
4.20 Statistical Techniques	17	6	13	6	17	6

The ranking of ISO 9001 clauses is presented in Figures 1 through 3.

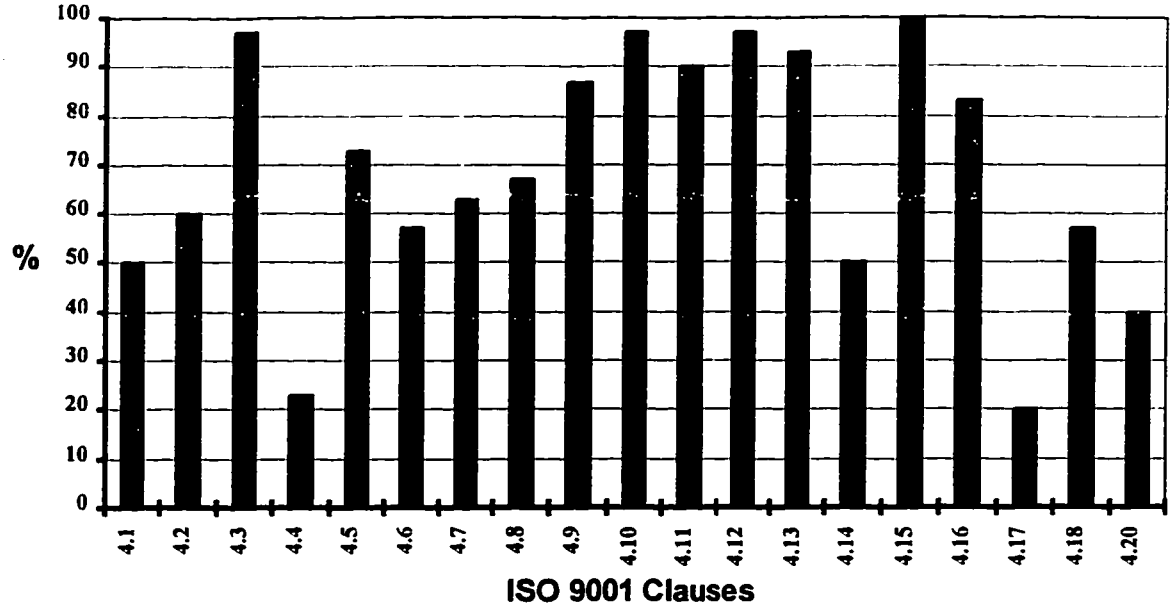

Figure 1 : Contractors Existing Quality Systems Elements Required by ISO 9001

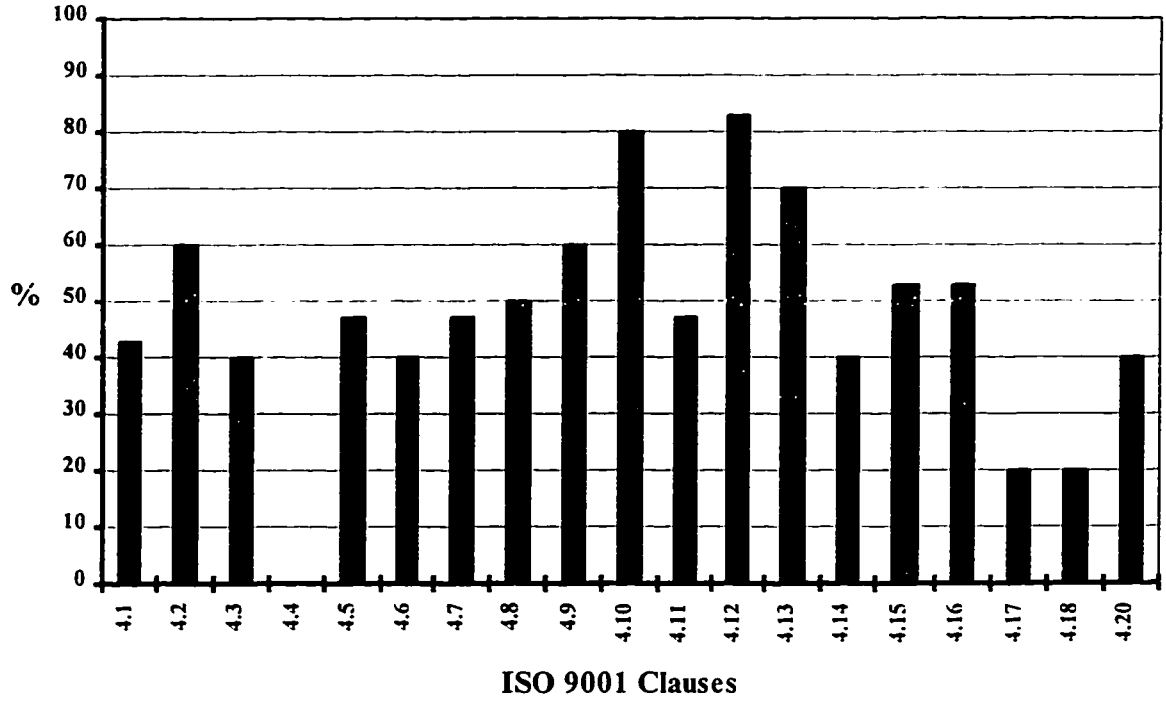

Figure 2: Contractors Documentation of Quality Systems Elements Required by ISO 9001

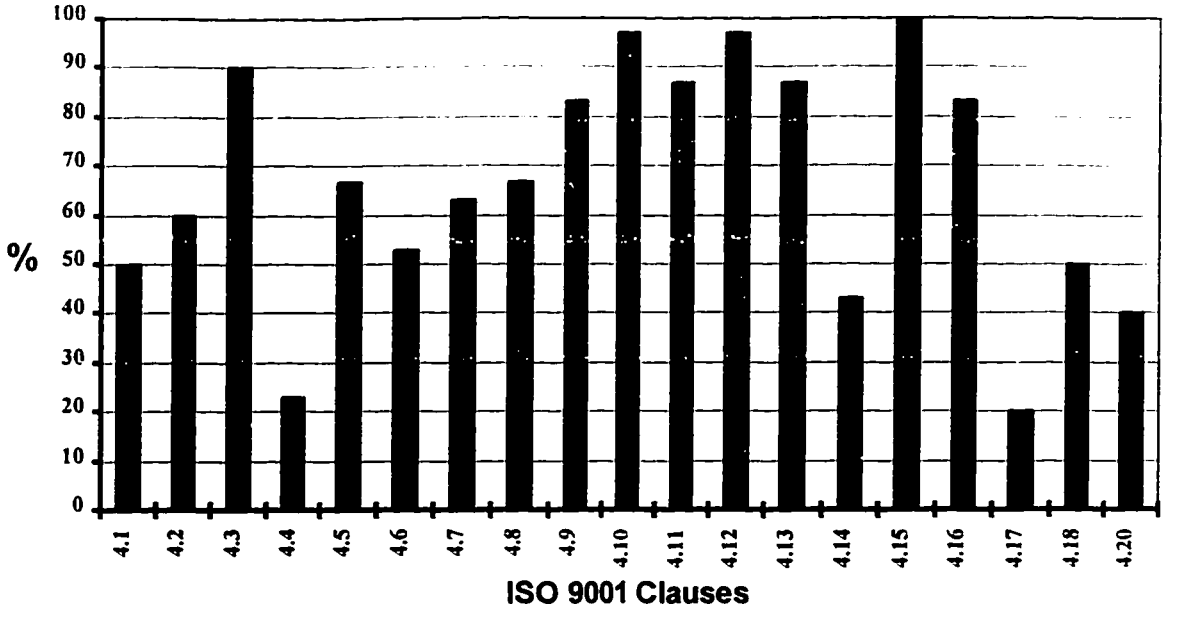

Figure 3 : Contractors Implemented Quality Systems Elements Versus ISO 9001

From Table 26 and Figures 1 through 3, it can be noticed that :

- Handling and storage (Clause 4.15) is the element of quality systems achieving the highest compliance of the ISO 9001 standard which the contractors have existing and implemented system for (note : all contractors agreed that packaging, preservation and delivery required by Clause 4.15 apply to products not for construction work). Contract review (Clause 4.3), inspection and testing (Clause 4.10) and inspection and test status (4.12) is in the second position.

- Internal quality audit (Clause 4.17) is the least element of quality systems of the ISO 9001 Standard which the contractors have existing and implemented system for. Design control (Clause 4.4) came in the second lowest ranking of the contractors' quality system. This is also due to the small number of contractors involved in the study that have design activities at all. Design control was followed by statistical techniques (Clause 4.20), and then management responsibility (Clause 4.1) and corrective and preventive action (Clause 4.14) are the clauses of ISO 9001 standard which the contractors have little applications.

- On the other hand, inspection and test status (Clause 4.12) is the most element of quality systems which the contractors have documented system for. This is followed by inspection and testing (Clause 4.10) and then control of non-conforming product (Clause 4.13).

- Internal audit (Clause 4.17), training (clause 4.18) and design control (Clause 4.4), are the least elements of quality systems which the contractors have documented system for.

It can also be seen that contractors documentation of their quality systems is lacking on most elements.

The output of the study raised the following concerns :

- The major factor of success to any quality system is the understanding, belief and commitment by the people who run it. If they understand it very well, they will believe in it, and when they believe in it they will implement it willingly, and constantly.

  It was found that companies who adopted ISO 9000 standard have done so mainly because the market is demanding it or will be. This is a reasonable cause but before the system is adopted, it should be understood and its benefits must be made clear to all management personnel and also to the employees who will implementing it.

  Those who already installed quality systems in line with ISO 9000 standard expressed that the quality of construction did not or only slightly improved. This indicates that there are serious problems in this area as ISO 9000 insists on continuos improvement and verification of effectiveness.

- The major focus of contractors' quality systems is on inspection and verification, and whenever something went wrong it would be fixed or something would be done about it. This is a "reactive" type of quality system which is not sufficient as far as ISO 9000 standard is concerned. ISO 9000 standard philosophy requires quality systems to be "proactive" rather than "reactive". In other words every possible arrangement must be made to prevent potential problems from happening.

- Eight of the contractors were confused between corrective action and disposition of nonconformances, and thought that they are both the same. Disposition of nonconformances is not enough. Problems are repeated because of improper corrective action.

- The effect of quality systems on improving the quality of construction must always be monitored and followed up. This could not be demonstrated by most of the contractors. It is an important issue especially in the periodic management review of the quality system (ISO 9001, sub-clause 4.1.3).

- The objective of internal quality audits must be, according to ISO 9000 standard, to verify implementation and to evaluate effectiveness. In other words, the auditor must not only check if the quality procedures are adhered to or not, but also to check if the procedures are adequate and efficient to achieve quality and assurance of quality. The contractors are lacking in the area of evaluating effectiveness.

- Three contractors advised that they are following the well-known saying that "all that ISO 9000 is about is that : you write what you do and do what you write". This is a misconception about quality in general and ISO 9000 in specific. Does this saying mean that it is acceptable to do a mistake constantly as far as it is documented ? Of course not. This misconception

must be replaced by the right concept of "Plan-Do-Check-Act" or the well-known PDCA cycle.

- Another area of concern for contractors - especially for those who have just get started with their new quality systems - is setting up priorities. Contractors should consider their company operations and put a list of priorities, starting by areas that needs immediate action and ending up with the least critical areas. For example, writing a procedure for inspection and test status (ISO 9001, clause 4.12) is not as important as controlling sub-contractors procedures (ISO 9001, clause 4.6), etc.

  The study showed this aspect has not been considered by the contractors. It was especially found with contractors who hire consultants to help in setting up the system. Consultants, in the case studies included in this survey, look at all elements equally. It is the role of the contractors management to identify the priorities for the consultants and their progress should be followed up.

CHAPTER 5

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary :

This research was intended to study the application of ISO 9000 series of standards in the construction industry and to conduct an assessment of the quality systems of fifteen major construction contractors in the Eastern Province of Saudi Arabia against the ISO 9000 standard. The fifteen contractors were visited to interview their concerned personnel and get the required information. The Questionnaire used during the interview consists of two parts; one was intended to learn how the contractor perceived the ISO 9000 standard while the second part to see whether the contractors have existing systems that meet the twenty clauses of the ISO 9001 standard and whether these systems are implemented and documented.

The ISO 9000 series of standards are international standards for quality management and quality assurance that are generic and intended to be applied in various industries including construction. Among the ISO 9000 series of standards, the three quality assurance standards, i.e. ISO 9001, ISO 9002 and ISO 9003, are used for contractual applications - between suppliers and customers - and for certification by independent third party certification bodies. ISO 9001 is the most comprehensive standard which has been selected to be the main evaluation criteria for the case studies.

Companies who intend to implement ISO 9000-based quality system are recommended to start with setting up internal quality management system using ISO 9000-1 and ISO 9004-1 standards before applying an external quality assurance system using the applicable requirements of ISO 9001, ISO 9002 or ISO 9003. Before all, contractors should understand the quality terminology using the ISO 8402 standard. Implementation processes should be gradual to absorb any resistance to change and limited capability of workforce. The objective of every element of the quality system should be made clear to the people involved in its application. This will help them in the implementation process.

ISO 9000 standard is a useful standard for construction contractors. The standard insists on the need for awareness, involvement and commitment to quality by all personnel of the construction organization; especially by top management. It requires identification of the role of every individual within the

organization and the interface between the various functional groups. It gives power to the QA/QC personnel and requires their authority and responsibilities to be defined. It insists on planning for quality and control of all stages of construction and related activities starting from review of tenders/contracts up to final completion and handover to the customers. It requires the quality system to be proactive rather that reactive, and emphasizes on the need for continuos improvement and self assessment of the contractor's operations and resources (i.e. personnel, equipment and materials) through verification, corrective actions, internal auditing and periodic management review of the quality system. It requires consistency in the contractors processes by having standard documented procedures which should be modified to suit the customer's project requirements. It requires the acceptance criteria of the quality of materials and workmanship to be objective (22).

However, there has been a reported criticism of this international standard within the construction industry; namely that this standard has been written for the manufacturing industry not the construction industry. This fact was supported by surveys in Europe in 1993 and 1995 which showed that unlike manufacturing and service companies, the European construction companies are dragging their feet towards ISO 9000.

5.2 Conclusions :

The following points have been concluded from the case studies :

1. The contractors quality systems vary in complexity ranging from an informal inspection and test system to a comprehensive system where inspection and testing is only one element among many others.

2. Two contractors from the case studies have been already certified by third party to ISO 9002, and four others are in the process to be certified. Four contractors have long term plans to fully implement quality systems that meet ISO 9000 standard while three contractors are not familiar with the standard.

3. Out of seven contractors who claimed implementation, only two contractors have quality assurance systems that comply with all requirements of the ISO 9000 standard. Ten contractors have limited project-wide quality control systems while one contractor has no formal QA/QC system.

4. Three contractors have been requested by their major customers (Saudi Aramco, SABIC companies and the Ministry of Defense and Aviation) to comply with ISO 9000 standard.

5. Too much paper work, control of sub-contractors and vague terminology are the difficulties identified by contractors in implementing ISO 9000 standard in their companies.

6. High cost, resistance to change, limited ability of personnel, remote job sites, cultural and language differences are the obstacles identified by the contractors who implement or intend to implement ISO 9000.

7. Management initiative, customers requirements and expected demand in the future are the reasons behind adopting ISO 9000 standard.

8. Out of the twenty clauses of the ISO 9001 standard, "Handling, Storage and Preservation", "Contract Review" and "Inspection and Test Status" are the most used clauses of ISO 9000 standard that the selected contractors complied with.

9. "Internal Auditing", "Design Control", "Statistical Techniques", "Corrective and Preventive Action" and "Management Responsibility" are the least implemented clauses.

10. The contractors documentation is lacking on most elements of their quality system.

11. There is a misconception by some of the contractors about some of the requirements of the ISO 9000 standard such as disposition of nonconformances and corrective action and internal quality audits.

12. There are problems encountered by the contractors due to improper contract review, document control (especially drawings) and calibration of measuring and test equipment.

13. General weakness of the contractors quality systems includes control of sub-contractors and training which are two major aspects that contribute to the quality of construction projects.

14. There is a misconception by some contractors about the objective of the ISO 9000 standard. They think that it only requires documented consistent level of quality - whether low or high - i.e. "write what you do and do what you write". Setting up priorities in developing the various elements of the quality system is not considered by the contractors who have just started developing quality systems in their companies.

15. Statistical techniques are applied by eight contractors; six contractors are using them for measuring productivity, while one contractor is using them for sampling inspection and the other contractor is using them for controlling welding procedures.

5.3 Recommendations :

1. In order to get the best results of the standard, contractors should increase the level of awareness about ISO 9000 standard. This will eliminate misconceptions about ISO 9000 and support the implementation process.

2. Contractor quality systems should emphasis on the importance of internal quality audits, corrective and preventive action, design control (if the contractors who do design), statistical techniques and management responsibility. These mentioned elements of the quality system received less attention by the contractors.

5.4 Recommendation for Further Studies :

Following are some of the topics which are recommended to be the theme of future research :

1. Third party certification bodies of quality systems in Saudi Arabia : The certification bodies can be surveyed to gather various information about their activities and to measure their compliance with the requirements of ISO Guide 48 (Guidelines for third-party assessment and registration of a supplier's quality system).

2. Quality assurance system of Architect /Design (A/E) offices in Saudi Arabia : Do the local engineering offices operate quality systems? Do they meet ISO 9001 requirements?

3. Quality assurance systems of geotechnical and materials testing laboratories in Saudi Arabia.

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Training	Attended conferences, symposiums and training courses on the ISO 9000 standard in Saudi Arabia, Bahrain and UAE and the UK.
Certification	Certified Lead Assessor of Quality Systems from the British Standards Institute (BSI-QA) since November 1995.

APPENDIX (A)

Part I : General

No.	Statement	Yes	No	Comments
1	We are familiar with the ISO 9000 standard. (In case you are not familiar, please go to the next page)			
2	We believe that ISO 9000 standard is applicable and beneficial to the construction industry.			
3	We implement the general principles of ISO 9000 standard in our Organization.			
4	The ISO 9000 standard requirements are difficult to implement in the construction industry.			
5	There are several obstacles that discourage the adoption of ISO 9000 standard in our Organization.			
6	Our customers require us to have a quality system that meets the ISO 9000 standard.			
7	We have the plan to be certified to ISO 9000 standard.			
8	Our quality system is certified to ISO 9000 standard.			

Part II : Quality System Elements

No.	Statement	Exist	Docum-ented	Implem-ented	Comments
	Management Responsibility				
1	Our management policy, objectives and commitment to quality are well defined and documented .				
2	Actions have been taken to ensure that the management quality policy is understood and maintained at all levels in our company.				
3	We have independent QA/QC personnel responsible to ensure and verify the quality of our construction projects.				
4	We have an assigned Quality Representative among our management.				
5	Our quality system is reviewed regularly by the top management to evaluate its implementation, effectiveness and possibility of change based on the feedback from customer complaints, internal or external audits, etc..				

No.	Statement	Exist	Docum-ented	Implem-ented	Comments
	Quality System				
6	Our quality system is documented in manuals, procedures and instructions to ensure compliance with the specified requirements.				
	Contract Review				
7	We have procedures to carry out and coordinate the review of customer's inquiries, contracts or change orders, to ensure that his requirements are identified, understood and achievable.				
	Design Control				
8	We have procedures to control every aspect of the design process.				
9	All design activities are planned, responsibilities and interface between the design groups are defined.				
10	Design activities are performed by qualified personnel equipped with all required resources.				

No.	Statement	Exist	Docum-ented	Implem-ented	Comments
11	Design input requirements are identified to ensure adequate basis for the design work. Design outputs are identified and include or reference to acceptance criteria.				
12	Design outputs identify those characteristics that are crucial to the safe and proper functioning of the facility to be constructed or its components.				
13	Design verification (including software validation) is performed.				
14	Design changes are approved and recorded.				
15	**Document and Data Control** All documents and data (including those which are relevant to quality, and subject to revision and issue such as quality manual, quality procedures, instructions, drawings, specifications, standards, etc.) are controlled and/or suitably approved before issue.				
16	Updated issues of the documents and data are made available to all personnel who need them.				

No.	Statement	Exist	Documented	Implemented	Comments
17	Obsolete copies are identified and removed.				
18	The master list that identifies the current revision of the documents is available.				
	Purchasing				
19	The list of approved sub-contractors (material and services sup-suppliers) is available and maintained.				
20	We have a procedure that identifies our criteria of selection and approval basis of our suppliers and sub-contractors of products or services.				
21	Qualification records of our suppliers and sub-contractors are available and maintained updated.				
22	All purchase and service orders include customer's contract requirements.				
23	Our purchase and service orders are clear, complete and precise. They are reviewed and approved prior to issue.				

No.	Statement	Exist	Documented	Implemented	Comments
	Purchaser Supplied Products				
24	Customer's supplied (free issue) materials, that are intended to be incorporated in their projects, are inspected for suitability prior to acceptance.				
	Product Identification and Traceability				
25	All parts of the construction work, materials or components are clearly identifiable and traceable to their respective drawings or specifications.				
	Process Control				
26	All construction or related processes are carried out and monitored in a controlled manner.				
27	Work instructions are given to the workers when necessary.				
28	Construction processes are performed under specified conditions, if necessary, and critical areas are identified.				

No.	Statement	Exist	Docum-ented	Implem-ented	Comments
29	The criteria of workmanship is stipulated to the greatest practical extent in written standards or by means of representative samples.				
30	All construction equipment are maintained per a pre-planned program.				
31	**Inspection and Testing** All construction materials and equipment are inspected for appropriateness and conformance to the specifications per inspection procedures.				
32	The stages of construction are subject to a documented inspection and test procedure or quality control plan to verify compliance with all project requirements.				
33	Hold points are established and indicated on the quality control plan to make sure that critical stages can not be exceeded until released from inspection.				
34	All completed construction works are finally inspected and tested per the quality plan or documented procedures prior to handover.				

No.	Statement	Exist	Docum-ented	Implem-ented	Comments
	Inspection, Measuring and Test Equipment				
35	All inspection, measuring and test equipment are controlled, maintained and calibrated per documented procedures, to ensure that their output readings are accurate.				
36	Calibration status of the inspection, measuring and test equipment is indicated on every equipment.				
	Inspection and Test Status				
37	The inspection and test status of the various construction activities is identified to preclude further/subsequent processing of inspected/unacceptable materials or workmanship.				
	Control of Nonconforming Product				
38	Nonconforming construction materials/workmanship, such as inadequate foundation materials or incorrect steel reinforcement, etc., are identified and handled per a documented procedure.				

No.	Statement	Exist	Docum-ented	Implem-ented	Comments
39	**Corrective and Preventive Action** All measures are taken to prevent potential causes of nonconformities.				
40	Corrective actions are taken to prevent reoccurrence of any nonconformance that may happen.				
41	**Handling, Storage, Packaging and Delivery** We always take all measures to prevent damage to/deterioration of construction materials prior to, during and after completion of construction activities prior to handover to the client. We instructed our sub-contractors to do the same.				
42	**Quality Records** We maintain all those records necessary to demonstrate achievement of the required quality and effective operation of the quality system.				
43	These records kept safely and easily retrievable.				
44	Retention period of quality records is defined.				

No.	Statement	Exist	Documented	Implemented	Comments
	Internal Quality Audits				
45	Internal quality audits are performed to verify implementation and evaluate the effectiveness of our quality system.				
46	We have a documented procedure on the methods of scheduling, preparing, conducting and reporting the quality audits and subsequent follow up.				
47	Internal audits are always performed by personnel independent of the functions being audited.				
	Training				
48	We monitor the performance of our construction personnel and those whose activities affect the quality system, and identify their training needs, and necessary training is provided.				
	Statistical Techniques				
49	We apply statistical techniques as a tool for quality assurance.				